THE PROVISION OF ANIMAL FODDER IN TROPICAL AND SUBTROPICAL COUNTRIES

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FOREWORD

Research on grassland management and fodder production in the tropics has not achieved the same stage of development as in the temperate zone, but several factors now operating are tending to give it a more prominent place among the agricultural investigations of a number of tropical and sub-tropical countries and regions. The main factors concerned are the development of mixed farming as the basis of a more settled and permanent system of agriculture, the realization of the value of a grass cover in conserving soil, and the attempt to raise the level of nutrition in the countries concerned by a wider use of animal products.

In order that a survey might be made of the present state of knowledge and experience on all aspects of fodder production from natural grasslands or cultivated crops in the tropics, invitations were sent to a number of the authorities and specialists concerned, in the hope that a comprehensive publication might be prepared. Owing to abnormal conditions connected with the war, some Departments were obliged to postpone the preparation of contributions until a later date. It has, however, now been possible to collect and publish as Part I of this publication a series of contributions that give an excellent impression of the problems experienced in the tropics, under both wet and semi-arid conditions, and of the extent to which these are comparable with the problems of temperate lands.

As might be expected, the species that are found in tropical grasslands or are cultivated for fodder are different in most cases from those of temperate lands. It is probably true to say that much has yet to be learnt of the forage value of the many species of Gramineae to be found in the tropics, before the selection of individual strains within species can be attempted. Only in the case of the more common and widespread fodder grasses such as Napier grass, Guinea grass, Rhodes grass and *Digitaria* has the recognition of different strains begun.

It has not yet been possible to create a pasture sward similar to that of the temperate countries, and the cultivated fodder grasses are generally cut and fed on the soiling system to stall-fed cattle. It has not been found possible to increase the protein value of the forage by the cultivation of grass-legume mixtures. Special leguminous crops can be grown under certain conditions and the leaves and fruits of leguminous shrubs can also be used. In fact, one author suggests the possibility of planting leguminous shrubs and trees in or near the grazing grounds or among the fodder grasses, or as windbreaks, hedges, shade trees, etc., for the creation of "protein pastures." The problem of a tropical pasture legume still remains a difficult one, however.

Most of the articles are concerned with the actual management of grazing areas, and its relation to soil conservation, pressure of stocking and population, native customs and religions, and so on. Reduction in stocking rates to permit regeneration of vegetation cover, and the conservation of fodder for use in the dry seasons are the two most important questions in the regions with distinct wet and dry seasons. Where grass farming is being practised on forest soils, the chief interest appears to be the development of a grass crop or a bush-grass fallow as the soil recuperative break in a settled or haphazard type of crop rotation.

It is not yet known to what extent a grass ley affects soil fertility under all conditions in the tropics. More will be learnt about this aspect when the contribution from Uganda can be published. If a grass break in a rotation is found to be desirable, it then becomes necessary to train cultivators in the technique of ley farming and to find species and varieties of herbage plants that are suitable and can be reproduced by seed or cuttings in sufficient quantities. Even if alternate husbandry is found to be applicable to the tropics in general, great care will have to be exercised in ploughing sloping land in areas with torrential rainfall, and the problems of the internal parasites and the other pests that affect animals under those conditions will require full investigation.

When it becomes possible to publish the remaining contributions to this symposium, the complete publication should provide a basis for the understanding of all aspects of the problem and for the development of practices and programmes of research for the different climatic and economic conditions that are to be found. Other aspects of fodder production in tropical countries are being covered in separate Bulletins and Joint Publications now in preparation, on subjects such as the fodder value and toxicity of shrubs and trees, the forage resources of Latin America, the production of fodder under irrigation, etc.

GRASSLAND MANAGEMENT IN THE WEST INDIES

Introduction

It is not possible at this stage in the agricultural development of the West Indies to write an authoritative article on " Grassland Management in the Caribbean Area " describing in broad outline but in definite terms present practice and essential improvements. The aggregate area covered by all the West Indian islands is not large in comparison with any of the major African colonies, and although the Islands all lie within the Tropics between 10° and 23° north latitude, they differ so radically in climate, soil, topography, social and economic conditions that any attempt to discuss their agriculture as if they belonged to one large ecological zone would be unwarranted. Within a single small island, the average annual rainfall in the wetter districts may be around 200 inches as compared with less than 35 inches falling in the same year in the drier localities (1). Apart from the effects of changes in altitude divergent ecological conditions are not uncommonly found in close proximity, and even the basic facts upon which a practical system of agriculture might be evolved for one district may not be applicable to a neighbouring locality less than 20 miles away. It is this highly variegated pattern of the cultivable terrain that makes agricultural planning peculiarly difficult and severely restricts the sphere of influence of results from applied research.

Nevertheless, the West Indian islands have at least one feature in common in that they all possess an insular tropical climate. The general trend of agricultural policy throughout the West Indies is towards a more self-sufficient and permanent agriculture involving intensified use of the land, expansion in animal husbandry, the growing of a greater proportion of annual food crops and the cultivation of a smaller acreage but not necessarily a smaller output of perennial export crops. Greater attention to the maintenance of soil fertility is required and soil erosion must be inhibited. This is the policy which it is hoped to pursue ; the effects of war have done something towards promoting the necessary change in the farmers' outlook, but the change over in method has not yet occurred. The unfortunate but inevitable intercalary period has been reached in which existing systems in respect of some staple crops are rapidly becoming moribund and the introduction of a better *modus operandi* is held up partly for lack of initiative and knowledge on the part of the farmer, but also because of the absence of fundamental data without which there can be no reasonable chance of success. The situation is aptly summed up in the following excerpt (1) quoted from the Report of the West Indies Royal Commission of 1938–39 :—

> " Substantial progress among both peasants and estates is dependent upon far reaching reform of the basic methods now in vogue. The practice of shifting cultivation by peasant farmers must be abandoned and replaced by an organised system of permanent mixed farming : the present policy of those larger proprietors who grow a single crop continuously must be modified by the development of mixed farming in a measure which will vary from place to place with local circumstances. Neither of these reforms can be successfully carried through until new knowledge, which is obtainable only by scientific investigation, has been secured."

Present Position of Fodder and Forage Grasses

Grass as a cultivated crop has in the past held no important place in West Indian agriculture. In most of the islands, cattle are the predominant livestock, but the number is limited and the forage and grazing areas are in general restricted to marginal soils and waste lands unfit for the cultivation of export or other money crops. With the notable exception of the better stock-rearing districts of Jamaica and possibly of parts of Puerto Rico and Tobago, the pasturage consists of mixed natural herbage and bush of low yield and poor nutritive quality, and the improvement of these rough grazings by some simple system of manuring and rotational grazing or by the breeding, propagation, and cultivation of better local or exotic pasture species has seldom been even attempted. Overstocking and selective grazing or mowing have tended to eliminate the small proportion of useful grasses originally present, and to open the way for serious soil losses by erosion and leaching. The time factor has therefore done nothing to improve the quality of the grazing grounds; rather the reverse.

In Jamaica, in contrast to this unsatisfactory condition of the grasslands of most of the West Indian islands, many of the ranches and dairy farms are located on fertile soils where relatively good cultivated and fenced pastures of Guinea grass (*Panicum maximum*) are rotationally grazed and otherwise carefully managed, albeit by methods based largely on tradition and individual experience. At intervals of a few years, rehabilitation of these Guinea grass pastures may be achieved simply and effectively by ploughing up or forking out the old grass after it has been allowed to mature sufficiently to set seed; a satisfactory spring of new grass from the shed seed may then be confidently awaited without further cultural attention. Although it is generally conceded that, on the whole, the Guinea grass pastures are the best, where environmental conditions are more suited to the cultivation of Para grass (*Brachiaria mutica*) or Wynne grass (*Melinis minutiflora*) these species may be used in preference to the Guinea grass. The Para and Wynne grass pasturage is also eminently satisfactory. Nevertheless, there is considerable room for improvement in the management of all these good grazing grounds. For example, no attempt is made to conserve the surplus herbage of the wet season for feeding to the stock in the dry period of the year. The stock-carrying capacity of the pasturage is thus limited to the number of animals it can support throughout the dry season, so that the head of stock actually fed off this apparently good permanent pasture seldom exceeds one beef steer to 2 or 3 acres. There is also room for improvement in the grazing system so as to adapt it to best advantage for the effective utilization of the protein-rich character of young herbage.

Agricultural research has in the past been concentrated on plantation crops such as sugarcane, cocoa, bananas, and citrus. The foundations for a programme of livestock improvement have also been laid but only limited investigation on the annual food crops of the smallholder—corn, roots, pulses,—has been undertaken. The scientific study of forage crops and of their place in animal nutrition and in the rotation has hardly been touched, while in the same period in temperate countries there has been a marked expansion on the investigational side of forage problems, from which a completely new conception of the importance of cultivated pastures and fodder crops for the evolution of an adequate system of land management has arisen. Moreover, although the potential productivity and nutritional possibilities of forage grasses and legumes have only recently been realized, the revolutionary discoveries

of the scientific research worker in this field have not been allowed to lie fallow but are already being widely applied to great advantage by the farming community in Great Britain. The stress of war and the need of feeding the stock entirely off the land have materially assisted this transference of research findings into field practice.

In the West Indies, where the natural conditions of soil and climate are particularly suitable for the luxuriant growth of many species of the grass family, not excluding sugarcane and maize grown for stock fodder, the present state of affairs relative to forage problems is markedly different and less satisfactory. If the stated policy for agricultural development is to be implemented, cultivated grass and forage crops must now take a leading position in the cropping programme, in order to facilitate an increase in the number of homefed livestock and to inhibit soil erosion under an intensified system of cultivation. The few scientific investigations with West Indian fodder grasses (for example 13 to 20) that have been completed have proved that the chief factors concerned with the efficient production and management of cultivated forage and pastures in cooler climates are equally important in the tropics. For long-term fodder crops and grasslands generally, a scientifically planned system of management, rotational mowing or grazing, appropriate manuring, the choice of a species, variety and strain well suited to the environment, the feeding of young herbage in preference to old are all fundamental to sound farming practice. Nevertheless, in the tropics, environmental conditions are so different from those in temperate countries that it is not feasible to put these principles into practice exactly along the lines that experience and investigation have proved to be most advantageous in the United Kingdom, for example.

It is not yet practicable in the wet tropics artificially to establish a temporary ley or permanent mixed sward which will be the equal of the best English pastures for purposes of stock nutrition and soil recuperation. In England, the economical production of good short-term leys as part of the crop rotation is considered by many authorities to be the key to success in any system of alternate husbandry. At present, the best fodder crops for the tropics appear to be the tall, erect, perennial grasses. They are commonly propagated vegetatively and produce a grass cover of individual stools, which do not even simulate the close matted sward and dense system of fine roots of an English pasture. It is not yet known how far these cultivated tropical grasses can take the place of a good mixed grass and legume sward for purposes of soil recuperation or for the control of soil erosion, and they may well prove to be less effective in these directions. On the other hand, it has already been demonstrated on a small scale that certain of these stool grasses closely planted in contour rows at suitable intervals on sloping ground can reduce soil wash to a negligible amount. Their effective utilization for purposes of controlling soil erosion or for building up soil fertility may therefore be only a matter of adapting the cultural method to the conditions. The average yield (14, 17) of green forage from cultivated tropical grasses should be double or treble that which is usually obtained from a good grass ley in England, and although the nutritional quality of the tropical herbage at its best is distinctly lower than that of young English pasture grass, the total yield per acre of digestible nutrient should be considerably more than that obtainable from pasturage in temperate regions with their shorter growing season, winter frosts and lower rainfall.

The Problem of Management

Enough has been written to show that the problem of grassland management in the tropics is radically different from that of temperate countries, and that scientific knowledge and research on the subject are still in their infancy. It should also be obvious why the scope of this article undertaken at the request of the Deputy Director of the Imperial Bureau of Pastures and Forage Crops is bound to be limited and why the paper has been given the title of "Grassland Management" in preference to "Pasture Management." Apart from the few exceptions already cited, any planned or controlled system of management of the forage fields is conspicuous by its absence and the grazing of the so-called pasture and waste lands is purely haphazard and indiscriminate.

No attempt is therefore made to describe present practice except *en passant*, but it is proposed to limit further discussion to the potential possibilities of cultivated fodder grasses and legumes in the West Indies, to indicate their importance in agricultural rationalization, and to suggest likely systems of management that might be used in different environments. Previous investigations with local fodder grasses have been so few and so restricted in character that any attempt to be dogmatic on any aspect of the subject would be unwarranted. In fact, the following ideas are in the nature of personal prognostications of the shape of things to come rather than the products of research and experience. It is certain that these hypotheses will have to be amended in the light of future knowledge and modified in accordance with actual as distinct from predicted agricultural development.

Forage Legumes

The list of short-term leguminous forage and cover crops that may be grown in the tropics is a long one, and in one locality or another of the West Indies most of the commonly cultivated species are found ; the following may be regarded as typical :

Bengal or Velvet bean	(*Mucuna aterrima*)
Bonavist bean	(*Dolichos lablab*)
Cowpea	(*Vigna unguiculata*)
Green gram	(*Phaseolus aureus*)
Soya bean	(*Glycine max*)
Woolly pyrol	(*Phaseolus mungo*)
Pigeon pea	(*Cajanus cajan*)

When they are cultivated as forage or green manure crops, they are relatively expensive to grow, limited and variable in their yields of green fodder, and have to be sown at seasons of the year when the land might preferably be used for some more valuable food crop. Although many of them may find a useful place in the farm rotation as pulse or short-season cover crops, it seems unlikely that any of them will ever have a revolutionary effect as soil recuperative crops or become the foundation upon which the maintenance of soil fertility can be ensured in any permanent system of agriculture. For this latter purpose, what is required is a long-term or perennial legume, easy and cheap to establish and maintain for a number of years, and capable of giving annually a good yield of protein-rich forage. In many subtropical areas, lucerne (*Medicago sativa*) does this satisfactorily and in cooler climates one or other of the clovers grown pure or in mixture with pasture grasses serves the same purpose. In the insular tropics no thoroughly satisfactory legume that can take their place

has so far been found, although the search for one continues. In Trinidad, it is possible to obtain a fair cover of the following more or less perennial legumes :—

Centrosema pubescens
Calopogonium mucunoides
Dolichos hosei
Indigofera endecaphylla
Pueraria javanica

They all tend to be slow in establishment, taking some 6 to 12 months to develop a satisfactory mat and afterwards requiring very careful management and periodic hand weeding in order to prevent them from being smothered and killed off by a profusion of the dominant weeds of the locality. The trailing indigo (*Indigofera endecaphylla*) is the most promising of the five listed above and it has already achieved a good measure of popularity in Puerto Rico (5) where it has recently been cultivated with some success for the purpose of controlling soil erosion and improving soil fertility. Evidently, in Puerto Rico and to a less extent in St. Lucia and British Guiana, conditions are distinctly more favourable for the cultivation of trailing indigo than in Trinidad, but even in those better localities it is still far from being the ideal perennial legume for the tropics.

Since 1936, the Imperial College of Tropical Agriculture has imported from various tropical countries a limited number of species and varieties of semi-perennial forage legumes including several strains of *Alysicarpus*, *Lespedeza*, *Stylosanthes* and *Pueraria*, but none of these introductions has passed the observation stage, and their potential value has still to be determined. Many of them have already shown themselves to be out of their proper environment, and in fact only Townsville lucerne (*Stylosanthes guyannensis*) shows much promise.

The task of finding a tropical legume that will effectively take the place in the rotation so adequately occupied under other ecological conditions by lucerne or clover is apparently not an easy one. The problem may well prove to be insoluble, and this makes the following innovation a particularly interesting one. In some parts of the West Indies, notably in Puerto Rico and Tobago, attempts are being made to improve the average protein content of the forage fed to livestock by establishing on the grazing grounds or among the fodder grasses a number of leguminous shrubs or trees. The young shoots and foliage from these leguminous trees are relatively rich in protein ; if some are included in the forage fed to animals, a better protein balance may be procured. The common practice is to allow the stock to browse from the trees for a limited portion of the time they are out to pasture, and to pollard the taller trees periodically so as to encourage a profuse growth of new shoots and leaves within easy reach of the livestock. The foliage could equally well be fed on the soiling system, probably with some advantage in the way of better control over the growth of the trees and the quality of the foliage fed to the stock.

The idea has distinct possibilities, especially as some of the legumes may be used not only as a source of nutritious forage, but also as windbreaks, hedges, shade trees, and even as soil recuperative agents. The commercial utility of such " protein pastures "—as they are termed—has still to be determined and the practical details of management have to be worked out with particular reference to the best species to use, the correct balance between the livestock and the legume requirements, and the effect of the trees on the soil and on its grass cover. Some of the species of legume that have been suggested for these protein pastures are :—

Bucare (*Erythrina berteroana*)
Nicaraguan shade (*Gliricidia maculata*)
Wild tamarind (*Leucaena glauca*)
Woman's tongue (*Albizzia lebbek*)
Mesquit bean (*Prosopis chiliensis*)

In addition to the value of the foliage for forage, the pods and beans from the last three listed make excellent concentrates for cattle. There is need for caution, however, in putting this " protein pasture " idea into practice until information on the subject is more complete. For example, it is known that horses and pigs fed on the foliage from the wild tamarind soon lose their hair (4), and that the new coat which may ultimately appear is often of a different colour and texture from the original hair. In contrast, cattle, goats, and sheep may be allowed to browse greedily on the wild tamarind with only good results. In Barbados, the *Albizzia* tends to develop a very deep root system, when it may be ineradicable and so become a noxious weed in cultivated land.

For the remainder of this paper, in view of the paucity of the existing information about all classes of tropical forage legume, discussion will be practically restricted to the available perennial forage grasses which may be propagated and cultivated in some part or other of the West Indies.

Potential Forage Grasses

The species* of grass at present found in the West Indies may be conveniently divided into three main classes in accordance with their general habit of growth.

A. Pasture or turf-forming species, comprising the more important bottom grasses capable of forming a more or less dense, close, turf sward.
   Savannah or carpet grass (*Axonopus compressus*)
   Bahama or devil or doob grass (*Cynodon dactylon*)
   Pimento or Buffalo grass (*Stenotaphrum secundatum*)
   Crab or St. Augustine grass (*Stenotaphrum secundatum*)
   Centipede grass (*Eremochloa ophiuroides*)
   Java grass (*Polytrias praemorsa*)

B. Trailing species which do not form any turf but produce a thick tangled cover 1 to 3 ft. in depth, composed of a profusion of intertwined leafy runners.
   Para or Mauritius grass (*Brachiaria mutica*)
   Molasses or Wynne grass (*Melinis minutiflora*)
   Seymour or Barbados sour grass (*Andropogon pertusus* = *Amphilophis* sp. ?)
   Star grass (*Cynodon plectostachyum*)

C. Tufted or stool-forming species, mainly tall, erect cane-like grasses.
   Elephant grass (*Pennisetum purpureum*)
   Guatemala grass (*Tripsacum laxum*)
   Guinea grass (*Panicum maximum*)
   Uba or other thin sugar-cane (*Saccharum sinense*)

Vernacular names. It is possibly advisable to point out that there is considerable confusion in the local names applied to crops and plants, and particularly to grasses throughout the West Indies. Vernacular names should not be used without specifying the corresponding generic name. For example, depending on the locality, sour grass may refer to *Andropogon pertusus* or *Paspalum conjugatum* or *Trichachne insularis*, and water grass may be *Commelina elegans* or *Brachiaria mutica* or *Panicum geminatum*.

The preceding list of grasses includes most of the known good forage or fodder species of the West Indies. Depending on the ecological conditions, the areas in which each species may be found as the dominant natural or cultivated forage grass tends to be restricted to a few special islands in each case, and even to certain clearly defined localities in these islands. The importance of ascertaining the species, variety and strain of grass likely to thrive and yield best in any given environment can hardly be overstressed. Arrangements for distributing and testing the more promising species over a much wider range of ecological conditions could advantageously be undertaken. The large number of different types and strains obviously present in existing grass populations would surely reward in full measure and at an early date any selection or breeding work undertaken by competent authority aiming at the improvement of the good species for the production of forage for grazing or stall feeding.

Pastures or Swards

Among the turf-forming grasses (Group A), there is at present no very good pasture species, as under existing conditions they all tend to be rather low both as regards yield and nutrient quality of the herbage (18). The remark made in the previous section about the possibilities of improvement from a well-planned breeding and selection programme is likely to be particularly true in respect of these pasture species. Even to-day, in certain parts of the West Indies, for example, Jamaica and Tobago, there are limited areas of relatively good pasturage composed of a more or less pure stand of one or other of these pasture species. Nevertheless, even in these presumably favourable localities, it is evident that there is room for considerable improvement in the productivity and stock-carrying capacity of such pastures by introducing better species or varieties either pure or in admixture, and by evolving an efficient grazing technique or other good system of management. The mere avoidance of obvious malpractices such as periodically overgrazing the sward for the sake of immediate needs at the expense of a progressively deteriorating pasturage may do much to effect early progress.

Savannah grass (*Axonopus compressus*) is probably the most widely distributed species, being the common lawn grass of all the wetter localities of the West Indies. Its yield and quality appear to be very variable, and the few data that have been recorded from samples taken in Trinidad (18) give figures that on both these counts are below those quoted for savannah grass grown in some other tropical colonies, for example, Malaya and Queensland (9). However, in suitable areas savannah grass is easily propagated vegetatively and is capable of producing a thick grass cover in the form of a reasonable sward in about a year from planting. With proper management and care, this sward should persist more or less indefinitely, but information is lacking to show how it will stand up to heavy mowing or grazing. In Trinidad, regular close mowing appears to render it more prone to serious attack by the various insect pests to which it is rather susceptible. The mole cricket (*Scapteriscus vicinus*) and the chinch bug (*Blissus insularis*) are the worst of these insect pests which periodically attack Trinidad savannahs.

Bahama grass (*Cynodon dactylon*) thrives in drier localities, particularly on well-drained limestone soils, and usually does well under conditions in which savannah grass would be at a disadvantage. It is the lawn grass of most of the dry tropics, and compared with savannah grass it produces a fine-leafed, closer-grained turf.

It is the chief component of the best commons and park lands in Barbados and in some parts of Jamaica. The herbage is relatively nutritious and has a high dry matter content, but the yield of green forage is generally lower than that of savannah grass; Bahama grass is subject to the same insect pests.

These two species, Bahama and savannah grass, each in its own environment, may with some degree of certainty be claimed to be the most important actual and potential sward grasses of the West Indies. Under existing conditions they are far from satisfactory pasture species, although they are found in greater or smaller proportion as the chief bottom grasses on practically every natural open grazing ground, and particularly in those that are kept close cropped. Their future potentialities for forage, pasturage, park lands, erosion control or soil recuperation are considerable, but their utility in any of these directions cannot effectively be assessed or defined, until their characteristics and requirements have been more accurately determined by scientific investigation. For the early improvement in the quantity and quality of local forage, now urgently required for the development of a system of mixed farming, they are not likely to take a prominent place. For the immediate future, their practical utility to the farmer will probably be limited to the provision of a satisfactory and persistent vegetative cover on communal grazing grounds or exercise paddocks or on sloping or other lands liable to suffer from soil erosion. It will be some time before their full potential value as forage or pasturage can be realized or exploited.

Fodder and Forage Grasses

All the trailing and stool-forming grasses (Groups B and C) are potentially good fodder or forage species, and depending on the environment and the type of farm, each might have its use. Assuming that they are required as long-term cultivated fodder crops, sown or planted on tilled land, and afterwards managed, manured and utilized on some scientifically planned system appropriate to the particular grass, it becomes necessary to indicate the conditions under which they should be grown if they are to play their proper role towards the fulfilment of a new agricultural policy. There is a wide range of soils and environments in which one or other of these grasses could be cultivated successfully, but it would be wasted effort to attempt to grow any of them in localities to which they are not naturally adapted. The surest method of approach in order to make reasonably certain that each species will be tested and cultivated to best advantage would be to await the completion of the general soil survey which is already in hand, and is being implemented with particular attention to the whole of the cultivable terrain in the West Indies.

With all reasonable expedition, some years must elapse before this survey can be effectively completed, even in very general terms, and these years coincide with a very critical period for the agricultural welfare of the West Indies. In fact, it is not too much to say that any further delay in beginning operations on a big scale for the promotion of a radical change in existing systems of agriculture may have serious repercussions. At the same time, the importance of trying to effect a reasonable balance between the need for immediate action and the risks of undertaking major reforms before scientific data on the subject are at all adequate is fully realized. Nevertheless, it is felt that if the problem is approached with skill and caution, much can be done in the next few years by means of trials, demonstrations, and other measures to promote public interest in the proposed new cultural practices and to

suggest appropriate methods for their effective and rapid introduction when the time comes. Concurrently, it will also be necessary to plan and carry out with the least possible delay scientific investigations designed in the first place to supply fundamental data of immediate practical value. The proposed soil survey undoubtedly belongs to the latter class of investigation, and it may be interesting to indicate how the results from such a survey would materially help in the planning of agricultural development.

When the survey is complete, each section of cultivated land can be correctly allocated to its own soil and ecological class. There are various alternative systems of classification that might be used and a system of the same general type as the land-use-capability scheme adopted in parts of the United States of America is suggested as being particularly appropriate. This system of classification (2) is based on the needs of the land from the soil conservation viewpoint. The scheme takes into consideration not only type of soil, its physical and chemical characteristics, its organic and mineral content, but it also puts stress on the liability of the soil to erosion as determined by such factors as slope, topographical position, susceptibility to floods, rainfall and other climatic conditions, and by the crumb structure and dispersion ratio of the soil particles. By this method, agricultural land may be subdivided into eight main classes. Classes I to III represent different grades of arable land, Class IV for the most part includes land that should be only occasionally ploughed, while Classes V to VII include areas that should be kept under permanent vegetative cover, and Class VIII is waste land of no agricultural value. For Classes V to VII, the sod-forming grasses, such as are mentioned in Group A on p. 8., would be more suitable than the species mentioned in the other two groups, but this does not entirely rule out the possibility of using some of the more matted types of trailing grass, provided the necessary precautions are taken against erosion during the period of establishment.

Classes I to IV are the best for the cultivation of high-yielding nutritious forage. The first three classes represent arable land presumably capable of growing a variety of food or money crops, and if the potential productivity of the soil is to be effectively realized, the fodder grasses should form an integral part of the crop rotation. The proportionate acreage under forage crops would depend on the particular farm and its system of management, but it would not be economical to put the land down to perennial grass for less than three years, or more than six years at a stretch, and a period about midway between those two extremes would probably be best. A grass crop of this duration would rest the land from the plough for a sufficient number of years to afford the grass a reasonable chance of assisting in soil recuperation, and of producing a large enough bulk yield of fodder to offset the capital cost of establishment. What other crops should be included in the rotation must remain a matter for conjecture, but on fertile land it is not unreasonable to assume that the total length of the rotation cycle should be about double that of the period under grass, and that in the second half of the rotation the land should be intensively manured and heavily cropped. This would probably mean that the equivalent of two successive short season crops would be taken off each field in each year. Climatic conditions in many parts of the West Indies not only make such double cropping of arable land practicable but also advisable.

The marginal arable land (Class IV) comprises soils and environments in which perennial fodder grasses could most appropriately be grown to immediate advantage.

Ecological conditions are such that satisfactory yields of herbage should be obtainable, but they would rule out any question of keeping the land intensively cropped solely under food or cash crops. On this class of land, a cultivated grass crop of a persistent species could profitably be allowed to run on without replanting for at least 10 or 12 years. This would spread the cost of establishment (which might be high in virgin areas) over a satisfactorily long period, and the maintenance costs, apart from utilization, could be restricted for all practical purposes to the manurial requirements necessary for the replacement of the soil nutrients removed in the herbage. Such a long-period grass crop would be expected to inhibit soil erosion, and also in some degree to build up soil fertility. For these purposes, it is likely that one or other of the trailing grasses (Group B) would be more successful than the stooled species. In suitable localities when the grass is ploughed under, periods of 2 or 3 years under food or money crops might be visualized, providing for a 12 or 14-year rotation cycle in all, with some 75 per cent of the total acreage under forage or fodder grasses.

On sloping ground, some system of contour strip cropping or of terracing may have to be practised as a protection against soil erosion. In such localities, strips of cultivated land should alternate with strips under permanent grass or other non-erodible vegetative cover. On the steeper slopes, it may be advisable to use one or other of the turf-forming species (Group A) for the grass strips, but where the necessary degree of protection could be provided by one of the forage species (Groups B and C) this would generally be used in preference, possibly in the form of a contour " hedge " along the upper and lower borders of each strip. In this latter event, the strips of forage grass would be treated as perennial and would not form part of the crop rotation, even though they might be expected to yield the bulk of the forage requirement for the holding on which they occurred. The rotation of crops and the length of the rotation cycle used for the cultivated strips would have to be different from those suggested for land in which most of the grass is grown as a rotation crop.

Cultural Factors

While the cultural details must depend on the species, soil, and method of utilization, certain principles which are generally true of the cultivation and management of all the grasses listed in Groups B and C can be set down. The importance of the correct choice of species and of variety for each environment has already been stressed, and it is unfortunate that, for some years to come, this choice must be guided largely by local experience and by a purely empirical knowledge of the various factors involved. The planting programme may not be held in abeyance pending the completion of further investigations. It becomes the more imperative, therefore, to draw upon all possible existing sources of information in planning cultural practice for the immediate future. Where there are serious doubts as to the suitability of a certain area for the cultivation of a particular forage grass, it is recommended that a number of carefully selected species should be grown on a trial scale for the first year or two. This would amount to the establishment of very small sub-experiment stations in all important areas where past experience has not already given some indication of their suitability for one or other of the perennial fodder grasses.

Existing information (11, 15, 17,) indicates that the tall cane-like grasses (Group C) are potentially the most capable of giving the highest yields of good nutritious

herbage, so that, other things being equal, one of these species should be selected. Elephant grass may be taken as a typical example of this group, as without any special cultural attention it is capable of yielding 60 to 70 tons of young herbage per acre per annum (11, 16). It also serves to illustrate another important principle, namely, the inadvisability of limiting the fodder crop on any farm to a single species. In Trinidad, elephant grass is liable to become heavily infested sporadically at intervals of 3 to 5 years with *Helminthosporium* sp. (a leaf-spotting fungus), which rapidly causes much of the foliage to wilt and die, and eventually kills most of the stools. Recently a strain of elephant grass, introduced from Uganda to the Imperial College of Tropical Agriculture, has shown itself to be fairly resistant to this particular *Helminthosporium* sp., but its degree of resistance when climatic conditions especially favour the fungus has still to be tested. In Jamaica, two distinct strains of Guinea grass (*Panicum maximum*) are already recognized. The first of these strains is grown at relatively high altitudes, while the second, which is resistant to rust, is cultivated on the plains. Again, in the summer of 1942 when most of the forage grasses grown on the College Farm were seriously defoliated by an epidemic infestation of striped grass looper caterpillars (*Mocis repanda*), adjoining fields of Guatemala grass were practically unaffected. It is recommended, therefore, that any new areas to be planted in fodder grass should be apportioned between at least two species of grass, preferably differing widely in their botanical characters, seasonal growth, and susceptibility to pests.

All the listed species are easily propagated vegetatively; they require a preliminary establishment period varying from 6 to 12 months, during which thorough cultivation, including weeding, manuring, and replanting of the blanks will be amply repaid by the production of thriving fields of forage in pure stand. Investigations at the Imperial College of Tropical Agriculture (16, 18, 20) have shown that the highest yield of nutrients per acre is obtained when the crop is cut over in rotation at intervals of 6 to 12 weeks, depending on the species. The grasses should be grown as long-period fodder crops, and if their full yield potential and powers of persistence and ratooning are to be realized, it is important to adopt a cutting rotation and harvesting technique suited to the particular species. With Guatemala grass, faster regeneration of the ratoons is obtained if the previous crop is cut at 8 inches to 10 inches above ground level (17), whereas with Para grass the crop ratoons most successfully when it has been mown at 2 to 3 inches. In the height of the wet season, elephant grass should be harvested at intervals not exceeding 6 weeks, but with Uba cane this frequency of cutting would be liable to kill off a proportion of the stools. Such practical details of management will have to be worked out for each species and each locality, if necessary by a process of trial and error.

Manuring

After establishment, any of the cultivated fodder grasses may be expected to give good returns of nutritious forage for a period of 3 to 10 years. At a conservative estimate, the yield should be at least 20 tons of fresh herbage per year. Assuming that this green fodder has an average of 20 per cent dry matter containing 6.25 per cent of crude protein (20), in the herbage alone some 90 lb. of nitrogen will be carted off the land each year. When it is remembered that the herbage may in addition remove annually in total minerals about ten times what it takes away in the form of nitrogen, it is obvious that even on a fertile soil in which the rate of natural nitrogen

fixation may be above average, high yields cannot be maintained without an intensive and well planned manurial programme.

It is reckoned that, in any system of mixed farming, the bulk of the available supply of farmyard manure could most profitably be utilized on the arable crops where the extra return in yield and quality of produce from good organic manuring is likely to be considerable. Furthermore, the effective application of farmyard manure to standing crops of perennial grass is very difficult to achieve in practice. Particularly under tropical conditions, if much of the nutrient value of the manure is not to be lost, it is essential to plough it under or to fork it into the soil as soon as possible after it has been spread over the field (24). With perennial fodder grasses, this covering of the manure could only be done at heavy cost and at the risk of seriously damaging the grass crop. On irrigable land, the raw dung and urine might be flooded on to the crop with the irrigation water, but in practice only a very small proportion of the total area under forage can be irrigated. In any case, this method of flooding the land with the washings from the byre may be open to the objection that it might encourage the multiplication of intestinal worms or other parasitic pests of livestock feeding on herbage manured so unhygienically.

Much of the value of farmyard manure lies in its ability to add to the humus content of the soil, but any good cultivated grass should in time be capable of doing this on its own account. Turner's investigations (27) on manuring sugarcane have shown that it is possible to obtain and maintain high yields of cane without organic manuring provided appropriate dressings of artificial fertilizers are applied. Therefore, it would appear that, as a general rule, cultivated fodder grasses could be manured most effectively and economically with suitable mixtures of chemical fertilizers. There will, of course, be exceptions to this rule. For example, on Class IV soils, there is likely to be a surplus of farmyard manure available after the needs of the arable crops have been adequately met; a heavy dressing of this organic manure ploughed into each field just before planting the new crop of fodder grass would be most beneficial in giving the grass a good start and in ensuring an initially satisfactory humus content in the soil.

What proportion of N, P, and K, should be used in manuring the land with artificial fertilizers must be determined by the particular soil type and conditions in which the crop is being grown, but it seems likely that most mixtures will require a high proportion of a nitrogenous manure for the maintenance of good yields of a protein-rich herbage. It is suggested that the annual dressing should be at the rate per acre of some 6 cwt. of a complete artificial fertilizer, say 3 cwt. sulphate of ammonia (20.6 per cent N), 2 cwt. superphosphate (18.2 per cent water-soluble P_2O_5) and 1 cwt. of muriate of potash (50 per cent K_2O). The fertilizer should be applied in three or four applications each year, being broadcast shortly after harvest between the rows of the grass on days when the herbage is quite dry.

Adequate manuring is also necessary for ensuring that the nutritional quality of the herbage is satisfactory, and Saint's interesting experiments (25) on the application of artificial fertilizers to sour grass meadows in Barbados effectively demonstrate that this problem of manuring perennial grass for high yields and good nutritive quality is thoroughly complex. It is not sufficient merely to know the main nutrient requirements of the soil in terms of N, P, and K, but information about the basic soil and grass reactions to different types, rates and proportions of the various fertilizers is essential to good manuring. Any important nutrient deficiency in the

soil will be reflected in a similar deficiency in the nutrient content of the herbage grown on that soil, and it is quite possible to obtain high yields of apparently first grade herbage which in actual fact is seriously deficient in one or other of the essential food ingredients, commonly in the protein or mineral content. The simplest and most economical way of guarding against such an eventuality is by the correct manuring of the soil. If the more soluble forms of artificial fertilizer are used, there should be an almost immediate response in a more vigorous growth of the fodder grass, resulting in the production of luscious dark green foliage which should be relatively rich in both protein and minerals, and ready for harvesting in a smaller number of days.

Investigations with pastures in England have shown that dressings of sulphate of ammonia considerably improve the protein content of meadow hay cut 1 to 3 weeks after the fertilizer has been broadcast on the pasturage (12), and there is no reason to doubt that similar types of response may be looked for from the manuring of tropical fodder grasses with chemical fertilizers. It is known that many of the existing natural grazings of the West Indies are located on soils which are markedly low or seriously deficient in one or more of their main mineral constituents (7, 8), and it becomes the more important in using such lands for the production of better forage to see that the manurial programme is adequate to the needs of both the soil and the fodder crop.

In this connexion, the possible importance of certain minor elements in animal nutrition and in the correct manuring of pasturage and fodder crops must be mentioned. The absence of one or other of these minor elements from the herbage of some pastures in the United Kingdom has not uncommonly been the cause of serious malnutrition, or of various obscure diseases prevalent among the animals grazed on these pastures. There can be no doubt that under tropical conditions the chances that the herbage may be lacking in some essential minor constituents are not less than in temperate countries. It is already reported, for example, that after a spell in some of the other islands, racehorses reared in Tobago do not stand up to the strain of the racecourse as well as they do in their home island, in spite of apparently equally good rations and stabling. Pressure of research requirements in other directions is likely to postpone any intensive study of these minor elements in the West Indies, but it is a line of scientific investigation that will ultimately have to be explored.

Another factor that is of considerable significance towards achieving effective manuring is the soil reaction. Most authorities agree that for the development of good pasturage in temperate climates a neutral or only slightly acid soil (corresponding to a pH of 7.0 or a little lower) is probably best, and that any soil where the pH is less than 6.0 is likely to be too acidic for the luxuriant growth of good forage grasses (6, 26). There are naturally many exceptions to this rule ; some greenkeepers even encourage a fair degree of acidity on land kept under close-mown fine lawn grasses since some of these species are most easily maintained on an acid soil which is detrimental to the multiplication of weeds or worms but apparently not to the growth of the lawn grass. Further investigation of the reaction of tropical fodder grasses to varying degrees of acidity in the soil is required, but in the meantime it is safe to assume that any excessive degree of acidity or alkalinity in the soil is inadvisable.

It has been suggested that heavy dressings of artificial fertilizers containing a high proportion of some nitrogenous manure should be applied to fodder crops annually. Certain fertilizers such as sulphate of ammonia may aggravate any tendency towards acidity in the soil, and it becomes advisable to guard against this

by regular light dressings of ground limestone. Where the soil reaction has been determined, the rate of application should be based on the lime requirement, but where the pH value is not known, a dressing every 2 to 3 years of 1 to 1.5 tons of ground limestone per acre may advantageously be applied ; it should serve as a safeguard for the maintenance of a satisfactory pH reaction in soils cultivated under perennial fodder grass. On markedly acid soils, an additional and heavier application of limestone either prior to the planting of the grass or at the time it is being ploughed out might be recommended on the principle that the value of the lime for correcting acidity will be realized more effectively and rapidly when it is thoroughly incorporated with the soil in the process of cultivation.

Utilization and Conservation

The detailed arrangements by means of which the forage reaches the livestock will vary from farm to farm, but all the different methods of utilization may be allocated to one or other of two alternative and contrasted systems, namely, utilization by grazing or utilization by stall feeding. The latter class includes the use of forage conserved in the form of hay or silage, but fundamentally it is a system based on the process of soiling in which the green herbage is cut and carted daily for feeding to stock at the steading. The advantages and disadvantages of soiling in comparison with grazing have been discussed at some length in an earlier paper (21). Both methods have their uses ; the former is especially appropriate where there is any question of land shortage or where grade milch cattle are the main class of livestock, as these require adequate protection against the hot tropical sun ; the grazing technique is generally preferable for the rearing and development of healthy stud animals and young stock and for the economical production of beef steers for the meat market.

Whenever there is a sufficiency of land, it seems likely that a combination of both systems (grazing in certain forage fields and soiling in others) would be best. In view of the fact that it is not every species of grass that may safely be grazed by all classes of livestock without damage to the grass, the areas reserved as pasturage will not generally be the same as those used for soiling, although with some species of forage there may be a certain amount of overlap.

The effect of the grazing animal on the forage crop (the biotic factor) is of such importance that it may not be ignored in any attempt to evolve a good system of management for the pasture land.

For example, fields of Guinea grass on which horses may be allowed to graze without fear of causing damage to the grass stools will not stand up so well to grazing cattle which are liable to tear out the Guinea grass herbage by the roots instead of clipping it off cleanly above ground with their teeth. For their effective utilization, the forage fields which are to be grazed will require to be managed with at least as much skill and attention as the fodder grass which is to be green-soiled. Rotational grazing will have to be practised but data are entirely lacking to indicate what rest period between grazings should be allowed for each species of grass and for each section of land.

Pending further investigations, it will have to be assumed that the number of weeks between grazings should be approximately that recommended for the same grass operated on the soiling system, say a rest period of from 6 to 12 weeks depending on conditions. Suitable methods for achieving this in practice have yet to be evolved and tested, but for the peasant farmer having only a few animals, a controlled system

of tethering or picketing could be adopted. For farmers owning a larger head of stock, temporary transportable fencing of strong but light hurdles constructed from local materials or alternatively the single-wire electrified fence of a movable type might prove practicable.

Whether the method of utilizing the forage is based on grazing or soiling, provision will have to be made for an adequate supply of fodder or roughage for feeding to the stock during the dry season of the year when the productivity of the fodder grasses may be very low or even negligible. The requirement in conserved forage varies greatly from island to island and with local climatic or farming conditions. In Trinidad, the dry season is not usually very severe or prolonged, and a supply of fodder in the form of cane-tops or similar roughage is usually available for the whole of the dry season. In some of the drier islands, the need for effective forage conservation is much more acute and the climate is such that it might be possible at certain seasons of the year to make a quantity of sun-dried hay. From the practical viewpoint, however, the flush period in the growth of the fodder grasses occurs at the height of the rainy season when there is likely to be a surplus of young herbage for conservation and storage. The wet months are not suitable for haymaking by natural means, so that the most practical scheme for conserving the necessary quantity of stored forage would be to manufacture silage in the wet season whenever the production of herbage is in excess of the immediate demand for green fodder.

This proposal is not intended to rule out the possibility of conserving at least a portion of the stored forage in the form of hay when the climatic conditions and the supply of herbage both favour its production. Moreover, the application of heat or the use of any suitable mechanical device for the artificial drying of green forage may in certain circumstances be both practical and economical. For example, on one estate, the " Chula " copra drier was temporarily adapted for drying grass, and the sample of " artificial hay " produced at a time when weather conditions were distinctly inclement was eminently satisfactory.

Nevertheless, for the immediate future the simplest and surest method of approach to impress upon the farming community the practical economy of conserving a portion of the wet season's forage would be to promote the manufacture of silage among all stock owners faced with a serious forage problem in the dry season. Within recent years, scientific knowledge of ensilage has greatly advanced, and with proper instruction and demonstration the manufacture of silage from suitable raw material could readily be brought within the capacity of the peasant farmer using improvized equipment.

However, it is important to avoid the errors which gave ensilage such a bad and unmerited reputation in Great Britain about the beginning of the present century, when the prevalent idea seems to have been that ensilage was a process whereby ruined hay or unpalatable roughage could be transformed into first-class food for stock merely by packing it haphazardly into tower silos. The resultant loss of faith in the process was both rapid and complete. Good silage may be guaranteed only when the scientific rules controlling the process are strictly adhered to in practice and when the raw materials are suitable and sufficiently nutritious to be worth the trouble and cost of ensiling. It is quite impossible to make good food from bad roughage by ensiling it, or even to produce edible silage from nutritious forage by a haphazard and careless technique.

A few experiments on the ensiling of tropical fodder grasses have only recently

been completed at the Imperial College of Tropical Agriculture. They indicate that the proven principles governing the manufacture of good silage in temperate countries hold good under tropical conditions. The essential scientific facts of the ensilage process are known, but some simple investigations to determine the economic methods of applying these principles to new types of raw material under the very different environmental and other conditions of the tropics have still to be undertaken. The early completion of at least a few such investigations on the practical aspects of the problem of making good silage from tropical forage would be of considerable assistance in giving definition and direction to the preliminary propaganda and proposals for its commercial production over an extensive portion of the stock farming districts of the West Indies.

The greater need in the drier islands for an adequate supply of conserved forage may be offset to some extent by the variety of short-season drought-resistant cereal or forage crops that may be cultivated for much of the dry weather. For example, it may be possible at the end of the wet season to sow a crop of Guinea corn (*Sorghum vulgare*) intended to mature and to be ready for harvesting for seed about the middle of the dry season. The grain could be used as a cereal for human nutrition, and the sorghum straw (which is said to have an unusually high feeding value as roughage) would materially increase the supply of coarse forage at the critical period of the year. In addition to Guinea corn, some of the lesser millets, for example, pearl millet (*Pennisetum typhoideum*), finger millet (*Eleusine coracana*), fox-tailed millet (*Setaria italica*), common millet (*Panicum miliaceum*), or alternatively short-term grass forage crops, for example, Sudan grass (*Sorghum sudanense*) or " Kyasuwa " grass (*Pennisetum pedicellatum*) might be grown as catch crops from seed more successfully in the drier islands than in the high rainfall localities of the West Indies.

The Improvement of Rough Grazings

Good permanent pasturage in the form of a nutritious close-cropped grass and legume sward is not to be found in the West Indies to-day. In its place, there are for the most part only rough natural grazings of various classes and types but all essentially low-grade pasturage. The few relatively good permanent grazings such as the better Guinea grass forage fields of Jamaica and Tobago are limited in number, area, and distribution, and for various reasons the head of stock they now carry is very low by European standards. However, the potential stock-carrying capacity of such pastures under a scientific and intensive system of management is considerable ; they do at least indicate that the production of rich tropical pasturage, albeit of a very different type from that favoured in temperate countries, is by no means impracticable.

It has already been suggested that early improvement in the quantity and quality of local forage is more likely to come from the cultivation of good strains of erect perennial fodder grasses than from any attempt to change the existing rough grazings into good permanent turf swards by the artificial introduction of better local or exotic pasture species. This does not necessarily mean that any hope of improving local grazing grounds should be entirely abandoned for a number of years to come. On the contrary, the general state of mismanagement under which all such grazing areas are now being operated should make possible a rapid and material increase in the yield and quality of local " pastures " merely by the introduction of a few simple and practical changes in the system of management and in the grazing technique.

There are admittedly certain areas such as the Rupununi ranching district of British Guiana (8) where the soil (which is basically infertile) has been leached of its limited supply of plant nutrients to such an extent that for many years ahead any attempt substantially to improve the grazing quality of such " ruinate " lands is likely to remain an uneconomic or impractical proposition or at least a doubtful gamble. In fact, tentative efforts at augmenting the yield of forage without scientific knowledge of all the fundamental factors involved may even be dangerous in that any increase in the stock-carrying capacity may possibly be effected at the expense of a progressive development of serious deficiency in some essential minor nutrient element.

It will suffice here to indicate some of the more important and obvious measures that a skilled manager in consideration of all the environmental factors might advantageously introduce in one form or another for the economic and material improvement of many of the existing rough grazings (with the possible exception of communal grazing grounds or " ruinate " range lands).

(*a*) *Rotational Grazing*

A simple but controlled system of rotational grazing must be practised to avoid some of the ill effects of overstocking and selective grazing. As already suggested, controlled grazing might be achieved by picketing, by hurdles, by movable ' live-wire fencing ' or by any other easily constructed practical device by means of which the daily grazing area of the livestock can be effectively restricted to any required section of the pasturage. Wherever more or less permanent live hedges can be advantageously established either around the outer boundaries of each field or possibly in hilly country in the form of contour hedges running across the slope, they would greatly facilitate the practical operation of any planned system of rotational grazing. The maintenance of such is a rural craft which may take some time to revive, but the idea is worth following up, particularly if the type of hedge ultimately established has nutritious foliage upon which the livestock may safely be allowed to browse. If the suggested ' protein pasture ' idea (Section 4) develops satisfactorily and proves a practical method of supplementing the ground herbage by the use for fodder of the protein-rich foliage from leguminous trees, it may be advantageous to have these forage trees planted over the grazing grounds in a checker board pattern of edible hedgerows ; at certain seasons of the year, it should be possible to arrange that these forage hedges are sufficiently proof to the passage of livestock that they will materially assist the practice of rotational grazing.

(*b*) *Rotational Stocking*

Where several classes of livestock—horses, cattle, sheep, goats or pigs—are being raised on one farm, the benefits to be derived from the rotational grazing of the pasturage may be considerably amplified by arranging that the different classes of stock are put out to graze in proper rotation. Sheep feed on the young tender bottom grasses, horses are very selective in their grazing habits in respect of species of grass and also of the section of the pasture field, cattle consume a good proportion of coarse herbage, and goats and pigs in a forage field are browsers and rooters respectively. These marked differences in the grazing habits of farm animals make the order in which they are allowed on to grass land a factor of considerable importance in the management of the pasturage to the best advantage both of the stock and the

pasture grasses. This idea of rotational stocking is by no means new; it is even practised to a limited extent on Jamaican ranches where the young stock gets the first bite from the best pasture fields, succeeded in turn by the milch cows and fattening stock, and last of all by the dry cows and old animals. The best methods of applying this principle to full advantage have still to be worked out for the various types of livestock and different farming systems.

(*c*) *Discouragement of Undesirable Species*

Under natural conditions, selective grazing tends to cause a progressive deterioration in the quality of the pasturage by encouraging the coarser and usually the less nutritious species of forage at the expense of the good grasses which are always the first to be consumed by the grazing animal. The periodic eradication or cutting back of undesirable species of weed and bush may be of great utility in the maintenance of a satisfactory proportion of the better species in the herbage. It is possibly unnecessary to add that known noxious or poisonous species should be dug out when they first appear, because the cost of removal should then be negligible and only a fraction of what may be required a few months later if they are allowed to multiply and spread.

(*d*) *Liming*

On soils which are known to be markedly acidic, the application of one or more tons of ground limestone per acre broadcast as a topdressing on the grazing grounds during the dry season might prove very helpful at no great overhead expense. It should serve in time to raise the pH reaction of the soil sufficiently to promote a more profuse growth of the better species of herbage and to discourage those others which are really indicators of excessive acidity in the soil and which have little nutritive value.

(*e*) *Shade Trees*

In tropical pastures, the need to provide some form of shade to protect grazing animals (especially grade stock with a proportion of European blood) from the hot mid-day sun has been mentioned. In the best of the present grazing grounds, shade trees are usually found, of which the Saman or Umbrella tree (*Pithecolobium Saman*) has shown itself to be excellent. It has the disadvantage of being a very slow grower, and for new pastures some other species (probably also a legume) may ultimately prove to be more satisfactory, especially if it can fulfil the double purpose of providing the required degree of shade and of yielding a certain quantity of nutritious fodder from its foliage or fruits. In planting such shade trees, it is important not to overdo the number which might convert the pasture field into a sort of open wood. The aim should be to provide the necessary shade without damaging the ground herbage: in fact, when the number and arrangement of the shade trees are correct, they should improve rather than detract from the grazing value of the area.

Actually, some of the best of the existing grazing grounds are really secondary grazings in which the grass is supplementary to the main staple crop, which is usually a relatively wide-spaced orchard crop. In Tobago, a vigorous and almost pure stand of Guinea grass (*Panicum maximum*) is found in most good coconut groves. Cattle are allowed to graze on this luxuriant natural growth of herbage under the coconut palms, which apparently provide the correct degree of shade to allow both the live-

stock and the forage grass to thrive. In places, the pasturage is so good that milch cows which have been allowed to graze there freely have maintained their full milk yield averaging between 2 and 3 gallons per day for the whole of their lactation period, without any supplementary concentrate ration. The cattle thus feed themselves at no cost to the owner, and the dung and urine they void help considerably in the manuring of the coconuts and in maintaining a luxuriant growth of herbage.

(*f*) *Drainage*

Effective drainage, but not over-drainage, is just as important for the maintenance of good pasturage as for the cultivation of arable crops. In permanent pasture having a perennial vegetative cover, it should be easy to ensure satisfactory drainage on all except swamp land or low-lying areas subject to heavy flooding or located below sea level. For example, on sloping ground, grassy contour banks or contour diversion ditches communicating at their extremities with properly protected drainage outlets (for carrying the water down the slope without causing gullying or scouring) should not be difficult to establish. The drainage requirements will depend on a variety of factors, but any drainage system should be planned to keep the water table near the optimal level for as much of the calendar year as is feasible ; it should also prevent prolonged flooding or complete drying out of the soil to a depth that is likely to be permanently harmful to the growth of the particular pasture grasses. Some improvement in the drainage of many of the existing grazing grounds could easily and simply be introduced, and might advantageously be undertaken.

(*g*) *Water Supply*

Wherever the livestock is kept on open range for days at a time, an unfailing and satisfactory supply of drinking water should be provided somewhere in the pasturage. In the wet tropics, there are so many simple and practical methods of arranging for this throughout the year that the number of waterless grazing grounds that are still to be found at least in the dry season is really inexcusable. The difference in health in animals that have free access to water at all times of the day and those that have only limited quantities of drinking water supplied to them as opportunity and facilities permit needs no elaboration here. Where the water supply is sufficiently plentiful and conditions are otherwise suitable, a little outlay on inexpensive pumping equipment such as the hydraulic ram or on irrigation channelling might make it practicable to deliver drinking water to most of the grazing grounds ; it might also allow a portion of the cultivated forage grasses to be irrigated in the dry season. The advantages of having even a limited supply of green forage throughout the calendar year are manifold.

* * * *

Most of the measures suggested for the easy and economical improvement of rough natural grazing grounds would apply equally forcibly to many fields of cultivated forage or fodder grass. It is only after due consideration of local and environmental conditions generally that any or all of these methods may effectively be adapted in practice for the improvement of any particular grazing ground. It is especially important that the experience and knowledge of the individual who undertakes the original planning should be adequate to the task.

Propagation and Research

Before the proposed schemes for agricultural development in the West Indies

can be fully and adequately implemented, it will be necessary to provide for considerable expansion in animal husbandry. The number of animals that each unit area of land carries to-day and the feeding standards for all types of livestock are both very low; even in the larger dairies, a high proportion of expensive imported concentrate foods is used to supplement very inferior roughage. Nevertheless, a few outstanding examples prove that it is possible to supply the bulk of the rations for both maintenance and milk production in the form of nutritious young herbage grown and consumed on the farm. From every point of view, this is undoubtedly the most satisfactory system of providing a balanced ration for livestock, but the supplies of herbage are totally inadequate at present to allow this method of feeding to become the general practice instead of the exception. The requisite increase in the total tonnage of nutritious fodder could most readily be achieved by planting a much larger acreage under good perennial fodder grasses.

The paucity of scientific information about the best methods for the cultivation and management of tropical forage crops would introduce some difficulties in implementing any such scheme, but it is considered that existing knowledge is adequate to allow the project to be put into operation forthwith with reasonable chances of success, always provided that, coincidentally with this development on the practical side, a carefully-planned programme of research on forage crops and animal nutrition is also undertaken.

In conclusion, it is proposed to try and indicate how progress in the field may most easily be attained, and to suggest the lines along which scientific investigation might most naturally operate. The following quotation (22) from Dr. I. B. Pole-Evans, formerly Chief of the Division of Plant Industry, Union of South Africa, is particularly appropriate, as it shows that it is not only in the West Indies that the inauguration of an adequate research programme on forage and grassland problems is considered to be the most likely approach to agricultural stability.

> ". . . . The start made by the State to foster grass and pasture research is the most encouraging sign of the times, and is the most powerful weapon that could be forged to meet the oncoming national crisis.
>
> "Pastoral research, if given full scope, holds the key to the preservation of our water and soil resources, the raising of our soil fertility, the revitalization of our agriculture, the termination of the drift from country to town, the production of more wholesome food, the creation of a more healthy people and a more contented and vigorous nation."

Assuming that in each of the islands the available grass species fit for cultivation as fodder crops are already known to the local stock farmers, even if only empirically, one to three of the best grasses should be chosen and an attempt made to establish them in small nurseries at suitable centres throughout the stock-rearing districts. In the Files, Reports, and Bulletins of the old West Indian Imperial Department of Agriculture will be found for most of the islands a considerable volume of facts and figures on the subject of grass species and indigenous flora generally, kinds of soil and their agricultural possibilities, composition and utility of the natural grazings, etc.; reference to these memoirs for the purpose of extracting any useful and applicable information about local forages might materially help in this preliminary selection of useful species. In some islands, there may be little or no choice, but where a grass is known to grow and yield even reasonably satisfactorily in a given environment, it is advisable to start with that species rather than to attempt to introduce and distri-

bute forthwith a presumably better species whose reactions to the environment are still untested and unpredictable. When the cultivation of forage grasses on a field scale has been started, these nurseries would serve as useful and essential sources of planting material. In Trinidad, for example, the immediate establishment of nurseries of Guatemala grass and of the Uganda strain of elephant grass is recommended.

In addition to the nurseries, at least one small experiment station for grass crops should be set up in each island, primarily for the introduction and testing of a few selected exotic species which are known to be good fodder grasses in some of the neighbouring islands having equivalent climatic and environmental conditions. Most grasses are easily propagated vegetatively, and, whenever it becomes necessary, the supply of planting material may be multiplied quickly by various techniques similar to those used in the case of new strains of sugarcane. None of the important varieties should be freed for general distribution until satisfactory information regarding its behaviour under local conditions has been obtained.

Concurrently with this propagation work, every effort should be exerted to make the farming community more " forage-minded " by propaganda, demonstrations, discussions and lectures on the cultivation, utilization, and management of the better forage crops for the area. To most farmers and land owners in the West Indies, " all grass is just grass " and this attitude of mind towards forage and grassland must be eradicated with the minimum of delay. All the preceding proposals for increasing fodder production could be undertaken by local Departments of Agriculture, which should also assume responsibility for the selection of the districts and soils that offer the greatest promise for early development. This question of locality is important, since a few initial failures or bad recommendations may set the whole scheme back a number of years.

On the technical side, the following would appear to be the natural order of events : first, the selection of one or more sites thoroughly suitable for fundamental research on forage problems, and the early establishment there of experiment stations fully equipped for comprehensive investigations on all aspects of forage production and ultimately of animal nutrition. These investigations might first be concentrated mainly on determining the main principles governing good field practice for the propagation, cultivation, utilization and management of the most promising of the available fodder grasses, such as has already been accomplished in Trinidad for Guatemala grass and elephant grass (17, 20).

The second line of investigation might be the selection and breeding for better forage grasses, starting with selection among the existing very mixed populations of known good forage species. The possibility of discovering new and useful species and varieties growing in some of the natural savannahs should not be overlooked.

Arrangements should also be made for introducing as soon as possible after the war a wide range of exotic fodder grasses which have proved themselves to be excellent forage crops in other tropical countries where the climatic conditions are similar to those obtaining in the chief stock-rearing areas of the Caribbean region. It is important that the number and range of such importations should be unrestricted, running ultimately into hundreds or even thousands of different species, varieties or strains. Along with this importation of exotic grasses, every effort should be made to discover or introduce a satisfactory perennial ground or tree legume for cultivation in each ecological district in the West Indies, either as a pure crop or in admixture with the fodder grasses.

Simple experiments of a practical type aiming at the definition and demonstration of the best methods for forage conservation in different ecological zones are also required, and such could be easily and quickly completed. The introduction of simple and inexpensive methods of conserving the surplus herbage at the height of the wet season might suffice to double or even treble the head of cattle maintained per acre of forage or grazing. Another useful line of applied research is the determination of the utility and economy for stock food of other local crops such as cereal grains, pulses, corn, etc. These crops will form part of the crop rotation in many systems of mixed farming and, if the produce or part of it may economically be used in place of concentrates to supplement the forage at certain seasons of the year, they may considerably help in the evolution of practical farming systems.

Subsequently, when these lines of investigation are progressing satisfactorily, the results should be translated into terms of practical utility in stock rationing by determining scientifically the exact nutritive and economic values of all recommended roughages, forage, pasturage, grains, pulses and concentrates. Long range and more fundamental types of forage problems will also have to be investigated, for example, the capacity of perennial tropical forage grasses and legumes for soil recuperation or erosion control ; the best balance between forage and food crops in the rotation ; the practicability of establishing artificially a long-term pasturage in the form of a mixed leguminous-grass sward of good productivity and satisfactory nutritive quality.

In forage and pasture investigations, undertaken in the tropics conjointly from the cropping and feeding aspects, there is undoubtedly a rich and interesting field for the scientific investigator to explore, involving both applied and fundamental research of immediate significance towards the development of a sound and rational system of agriculture. The present lack of information on the subject is a real handicap to those responsible for putting agricultural policy to practical effect, and a properly planned research scheme is not only urgently called for, but is also likely to bear rich fruit at no distant date.

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HAWAII : VEGETATION ZONES

The Hawaiian Islands show great variation in topography, altitude, soils, and rainfall. Thus the coastal plains change through steep slopes to high mountains of up to 1300 ft. ; the soils vary from new lava and young soils to well-weathered lateritic types, and the rainfall from 10 to over 250 inches per annum. Since these variations may be found within a distance of but a few miles, striking differences are seen in natural vegetation, cultivated crops and in agricultural practices.*

The climatic conditions obtaining in the islands are discussed by Stephen B. Jones, who makes the suggestion that sun temperature measurements, with black-bulb thermometers or thermographs, seem to have a closer relationship to plant growth than have the shade temperatures generally recorded.

Information regarding the plant cover of the Hawaiian Islands dates from 1778 when they were discovered by Captain Cook. The flora is interesting because 85 per cent of the 1,200 native species recorded are to be found only in Hawaii. The number of introduced species is something over 2,000. The effect on the indigenous flora of man's influence in introducing new species, clearing the trees and plant cover preparatory to cultivation, the use of the fire-stick, and the imposition of the grazing animal has been profound.

The vegetation has been classified into five major groups :

(*a*) shrub, chiefly along the coastal lowlands ;
(*b*) forest, 1–7,000 feet ;
(*c*) park-land, at about 7,000 feet where dry cool conditions prevail ;
(*d*) bog, 4–6,000 feet where the rainfall is very high and the topography level with poor drainage ;
(*e*) the moss-lichen formation on the high mountain above the timber line.

Following on the vegetation survey, the relationships between vegetation, rainfall and altitude were worked out, and tentative zonal boundaries fixed. These latter were based on certain isohyets and altitude limits at which transition in vegetation types occurred. The location of any boundary was revised where necessary in order to bring it into closer harmony with such transition. The zones therefore represent the general aspects of the vegetation as it now exists, and provide a means of correlating the essential features of environment with agricultural use. Zones are designated by the letters A to E, and where sub-divisions into phases based on altitude have been made the increasing heights are denoted by the figures 1 for low, 2 and 3 for higher phases. There are ten divisions in all, and below 6,000 feet they more or less conform to total rainfall. Above this altitude, as rainfall data are not generally available and since temperature then becomes the factor controlling growth, the regions can be satisfactorily sub-divided on the bases of altitude alone.

Zones A and E2 represent the extreme environments in which seed-bearing species will grow, B and C have seasonal climates and show the greatest numbers of annual herbs and grasses, while D with its ample rainfall has a predominance of perennials.

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*Review by A. R. Beddows of a publication by J. C. Ripperton and E. Y. Hosaka entitled "Vegetation zones of Hawaii," published as Bull. 89, 1942, of the Hawaiian Agricultural Experiment Station. Pp. 60 and 3 coloured maps.

The zones and their pastures

Zone A is found chiefly on the leeside of the islands between sea-level and 500 feet, but on some slopes it may extend to 2,000 feet. Except for the cultivation of sugar cane in those areas where water is available, grazing is the only important land use. The mean annual air temperature at sea level is 75°F. The rainfall varies between 12 and 20 inches, but long dry periods are common. Wind and water erosion are severe on the slopes because of insufficient plant cover. The soils are chiefly alluvial and vary from heavy black clays to sandy loams, but on the slopes friable red-brown soils of laval origin occur.

The vegetation is mainly of the lowland shrub type, except for the coastal fringe of algaroba trees (*Prosopis chilensis*), the pods of which drop when ripe and are greatly relished by cattle. Useful herbaceous plants are Australian saltbush (*Atriplex semibaccata*) often conspicuous on the flats, Spanish needle (*Bidens* sp. ?) false mallow (*Malvastrum coromandelianum*) and nettle goosefoot (*Chenopodium murale*).

Annual grasses are abundant after rain. Bristly foxtail (*Setaria verticillata*) grows under the algaroba trees and forms acceptable forage even when dry. Other grasses are swollen finger grass (*Chloris inflata*), feather finger grass (*C. virgata*), and several short-lived native *Panicum* spp. The most important grass is pili (*Heteropogon contortus*), and, although an annual here, is longer-lived than the other grass species. The finger grasses are of value where better grasses will not grow.

Among the newer introductions showing most promise are *Panicum coloratum* (Buffel grass), *P. prolutum* (Klein's Buffel), *Andropogon pertusus* (pitted beard grass), *A. barbinodis* (fuzzy top) and *Cenchrus biflorus*.

The factors which limit improvement in this zone are aridity and the lack of suitable perennial species. Several hundred species introduced from other arid parts of the world have been tried without success. The thinning out of the dense algaroba thickets encourages the entry of annual grasses. In the small valleys where the scanty rainfall concentrates, Guinea grass (*Panicum maximum*) and pili can be established. Where control of the grazing is practised, the ground cover is improved but recovery is very slow. The usual grazing practice is to move the breeding herd and calves to the algaroba areas when the beans begin to fall. Further grazing is possible when the annuals start growth following winter rain ; if the rain is fairly copious the animals grow rapidly and fatten well.

Where irrigation water is available, fodder production for dairy cattle is a common and economical practice. The species used are Napier grass (*Pennisetum purpureum*), Guinea grass, and the shrub, koa haole (*Leucaena glauca*).

Zone B lies at an average height of 2,000 feet, and is generally situated above A. Below 1,200 feet, where water is available, sugarcane is successfully grown, above this altitude pineapples, but otherwise the area is used mainly for grazing. The climatic conditions approximate those of A except that the rainfall may reach 40 inches or even more. The plant cover is therefore better and as a result erosion is less severe.

The vegetation is still of the lowland shrub type with algaroba prominent where the zone borders the ocean on the leeward side. Lantana (*Lantana camara*) and cactus may form dense thickets choking out all undergrowth. Cactus is generally regarded as a pest, but in certain areas in very dry years it provides the only source of water. Annuals or short-lived herbs are a prominent feature during the rainy seasons. The best forage herbs are saltbush, Spanish needle, red pualele

(*Emilia sonchifolia*) and horse weed (*Erigeron albidus*). Little beggarweed (*Desmodium triflorum*) is widespread but is too small to have much value as forage.

Of the shrubs koa haole is particularly valuable, and can often be established from sowings made either in open ground or in lantana thickets.

Pili grass (*Heteropogon contortus*) is perennial in this zone, and here attains its optimum growth. If rested it will maintain itself by self-seeding. In the case of Natal redtop (*Tricholaena repens*), its free seeding habit has enabled it to spread over most of Zone B, where it has been of especial value in colonizing areas which previously had little grass cover. Sour grass (*Trichachne insularis*), a pest in certain areas, is tending to spread.

The annual grasses provide valuable forage, and, in addition to those named for Zone A, the following are found :—smooth kukai puaa (*Digitara* sp.), hairy sandbur (*Cenchrus echinatus* var. *hillebrandianus*), hakonakona (*Eragrostis amabilis*), kakonakona (*Panicum torridum*) and *Panicum* spp.

In planted pastures, the most commonly used species are koa haole, Guinea grass, and giant Bermuda grass (*gynodon dactylon*) ; other valuable types are Rhodes grass (*Chloris gayana*), a heavy yielder, and Napier grass, but the latter is not so popular as Guinea grass, which has in places perpetuated itself by self-seeding. Molasses grass (*Melinis minutiflora*) is extensively sown, since the seed is cheap and becomes established rapidly, but it makes only limited growth.

Less widely distributed, but still valuable, are fuzzy top, pitted beard grass, Australian bluegrass (*Andropogon sericeus*), Wilder grass (*A. nodosus*), the shrubs, *Desmanthus virgatus* and *Desmodium tortuosum* (Florida beggarweed).

Recent introductions are *Panicum prolutum, P. coloratum, Brachiaria brizantha, Pennisetum ciliare,* and *Cenchrus biflorus.*

The annual legumes, Indian sweet clover (*Melilotus indica*) and bur clover (*Medicago hispida*), are locally prominent during the winter and spring months, when they greatly increase the value of the grazings.

Pasture development in zone B has in recent years been more extensive than in any of the other zones. This has been primarily due to two factors, the first being the recognition of the exceptionally high quality of the forage in these drier sections, and the second, the utilization of heavy mechanical equipment such as tractors, bull-dozers, and special cut-away disc ploughs. These implements make the clearing of lantana and cactus and the subsequent cultivations a more economic proposition than with the use of hand labour. Approved soil conservation methods of pasture improvement in contour furrowing and planting are beginning to be practised.

Zone C generally lies above zone B in fairly extensive plateaux. It ranges from sea-level to 4,000 feet. The effect of altitude on the vegetation has necessitated sub-division into two phases. The lower is adapted to more tropical crops such as sugar and pineapple, and the upper to crops from the more temperate zones, for example, maize, cereals, potatoes and legumes. The rainfall is usually adequate to support a fine tree growth and excellent pasturage throughout the year. It is the zone best adapted to non-irrigated agriculture.

The natural vegetation of the lower phase consists of shrubs and grasses, and it is considered that the lower vigour of the former is due to the greater competitive effect of the latter. Ploughed lands develop vigorous stands of various herbs which are, however, largely suppressed by Bermuda grass when once it becomes established.

In zone B such control is impossible as no perennial grass is sufficiently aggressive under those conditions.

In the higher phase, much of the original forest has disappeared, and in the more open spaces the shrubs aalii (*Dodonaea viscosa*) and puakeawe (*Styphelia douglasii*) predominate with some undergrowth of grasses. The cleared areas are essentially grassland, and little difficulty is experienced in preventing the encroachment of shrubs and trees.

The most valuable gramineous species is Bermuda grass. It provides good forage, stands up to hard continuous grazing, is effective against erosion, and is dominant over much of the better grassland areas. On the steeper slopes and poorer soils, a good covering is provided by pilipiliula (*Chrysopogon aciculatus*), yellow foxtail (*Setaria geniculata*) and rice grass (*Paspalum orbiculare*). In the wetter areas where the soils become compacted because of trampling, or where the fertility is lower, rattail (*Sporobolus capensis*) tends to become dominant. This grass is well grazed when young. Natal redtop is a valuable species of general distribution that behaves as a short-lived perennial. It volunteers in any ploughed or tested field, and is very conspicuous in the drier areas where the climate is more seasonal. Smooth kukai puaa does not give much keep, but it is generally well eaten and is fairly persistent in permanent pasture. Carpet grass (*Axonopus affinis*) was formerly much used in the cool moister parts of the upper phase. It is very aggressive and persistent, but is now generally regarded as inferior.

Paspalum dilatatum is undoubtedly among the most important of the planted species. It was extensively utilized early in the century and still persists. For pastures where it has apparently been smothered out, an excellent stand may be obtained merely by reploughing. Since *P. dilatatum* is not sensitive to temperature, it will grow from sea level to 5,000 feet. A similar tolerance is shown by Kikuyu grass (*Pennisetum clandestinum*), a more recent introduction which has not the palatability of *Paspalum*. It is, however, easily established and effectively holds plant pests in check; its aggressive nature also enables it to dominate the sward and form a "one-grass" pasture.

The leguminous shrub, *Cajanus cajan* (pigeon pea), was formerly much used in the higher phase, and greatly valued as a forage plant. Unfortunately it does not persist beyond 4 to 5 years if heavily grazed. This species offers scope for the selection and breeding of more suitable strains. Legumes common to temperate zones have been successfully established; for example, vetch (*Vicia sativa*), black medick (*Medicago lupulina*), bur clover (*M. hispida*) and Indian sweet clover (*Melilotus indica*) occur throughout zone C. They are found as winter annuals in the low phase, but in the high phase growth begins early in spring and the seed matures during the drier summer period. White clover (*Trifolium repens*) is found in the upper phase adjoining zone D.

The rougher lands can often be improved by broadcast seeding alone and thus provide excellent grazing for breeding and young stock throughout the year. Planted pastures may be seeded to paspalum or Kikuyu or to the larger species such as Napier grass, Guinea grass and pigeon pea. Temporary pastures as a part of the farm rotation also have possibilities, since the seeded grasses establish themselves quickly.

The pastures require careful management if they are to be maintained in the best condition. Aggressive species like Bermuda grass and Kikuyu require to be controlled; this is usually done by periodic ploughing—say every 5 years. This

system also restores the secondary species. Control of the grazing will enable the annual grasses and clovers to reseed themselves. Sometimes the cost of ploughing is recovered by sowing maize.

Shrub control is a difficult problem, which periodic ploughing only solves temporarily. Burning is also practised for this purpose as well as for removing the dense mat of dry foliage in Bermuda grass sods, but it has to be done with great care and not too frequently. Power mowers have recently proved very effective against pamakani (*Eupatorium adenophorum*), Sacramento bur (*Triumfetta bartramia*) and *Melastoma malabathricum.*

Zone D, situated mainly on the windward side of the high mountains, has been subdivided into three phases. It has adequate or even excessive rainfall.

Cool temperatures and frequent fogs produce conditions comparable to the humid parts of temperate zones. There is therefore less seasonal fluctuation in forage types, the perennial grasses predominate and annuals are of little importance. The three phases show marked differences in adapted species and pasture value.

In the low phase, the natural grasses Hilo (*Paspalum conjugatum*), rice grass, yellow foxtail and Glenwood grass (*Sacciolepis contracta*) are low in both nutritive value and palatability. Carpet grass was introduced to replace Hilo, but it is now regarded as inferior to the latter. The most widely distributed forage legume is the sensitive plant (*Mimosa pudica*), its importance being due to the fact that no other suitable legume is available. Kaimi Spanish clover (*Desmodium uncinatum*) has greater possibilities than ordinary Spanish clover as a pasture legume. Pigeon pea grows vigorously in the drier areas but is not very palatable.

Manuring experiments suggest that heavy applications of lime and phosphate stimulate the growth of herbage plants and increase their mineral content.

In the middle phase of zone D, the formation of pastures is restricted because of the high cost of clearing the forest, and also because of the constant menace of guava (*Psidium guajava*) and false vervain (*Stachytarpheta cayannensis*). When such areas are cleared the grass generally used is Kikuyu.

The high phase of D contains some of the oldest pastures in Hawaii. The relatively open koa (*Acacia koa*) forests and the cool moist climate are ideal for many of the best pasture species of the temperate zone. On several ranches, Kentucky blue grass (*Poa pratensis*) is an important constituent of the sward. *Lolium perenne* has also been used, but it succeeds only when the soil and management are good.

The case of sweet vernal grass (*Anthoxanthum odoratum*) is interesting, since it shows a strong tendency on improved ranches to dominate the sward. Though fairly palatable in the younger stages, it matures rapidly and is then neglected by stock. Yorkshire fog (*Holcus lanatus*) is a very prominent constituent of the swards in the open forests. Carpet grass was extensively used in former years, and it still forms the dominant species in some pastures. Kikuyu is now extensively used even up to 6,000 feet. Species of lesser importance are cocksfoot (*Dactylis glomerata*), large canary grass (*Phalaris tuberosa*) and tall oat grass (*Arrhenatherum elatius*).

The legumes found include white clover, which is widespread and prominent in well-grazed swards of *Poa pratensis* and Kikuyu ; vetch is adapted but does not persist under grazing, while hop clover (*Trifolium procumbens*) is widely distributed.

The herbs, dandelion (*Taraxacum vulgare*), wild geranium (*Geranium carolinianum* var. *australe*), and plantain (*Plantago lanceolata*) add considerably to the forage in places.

Management is of the utmost importance. The best improved swards deteriorate rapidly if overgrazed. Occasional ploughing or merely periodic resting will often restore the original mixture. Considerable improvement in pastures is also possible by broadcasting white clover.

Zone E with its three phases extends from 4,000 to 10,000 feet, but it only occurs on the islands of Mani and Hawaii, where it consists of the dry upper slopes of the high mountains. The shallow soils and low temperatures restrict agriculture to ranching, and this mainly to the low phase.

The vegetation consists of plateau and mountain-parkland types—scattered clumps of trees with open grassland between. The grasses are chiefly indigenous heu pueo (*Trisetum glomeratum*), mountain pili (*Panicum tenuifolium*), mountain love grass (*Eragrostis leptophylla*), kalamaloa (*Deschampsia nubigena*), brome fescue (*Festuca dertonhensis*), and rattail (*Sporobolus capensis*).

Introduced species are restricted to certain areas; *Poa pratensis* and *Trifolium repens* are confined to areas where phase E1 lies above D3, while the annuals, brome grass (*Bromus catharticus*), black medick, bur and Indian sweet clover are better adapted to the area above C2. Sweet vernal is especially abundant in the windward areas and has displaced the well-established more desirable Yorkshire fog in certain localities. In the more arid sections where Yorkshire fog is not so well adapted, sweet vernal is said to have increased the stock-carrying capacity of the pastures. Few of the grasses adapted to cold arid climates elsewhere have persisted when introduced to this zone. Wallaby grass (*Danthonia semi-annularis*) is well established on one ranch, while crested wheat grass (*Agropyron cristatum*) has been successfully tried recently.

Certain deep soil sections on the leeward side are ploughed and sown with maize and oats for hay. Excellent pastures can then be established in these areas by using ryegrass, brome grass, Kentucky blue, smooth-stalked meadow grass, black medick and bur clover.

The number and species recorded as occurring in the permanent pastures of the Hawaiian Islands is 316. These have been tabulated and classified under grasses and sedges, herbs, ferns, shrubs, and trees. The tables give the common and Latin names, the islands on which the species occur, and their relative abundance in each of the zones.

The number of species important for forage is relatively small, and the number which would be recommended for planting on the ranges smaller still. Classification of species on the basis of desirability or otherwise was not practicable as species differ considerably in value from zone to zone and even within zones. Thus, sweet vernal is an asset in the sparsely covered lands of zone E, but a pest in the improved paddocks of zone D3. Kikuyu tends to become dominant in swards of C2, but its aggressive character makes it capable of competing with guava, Hilo grass and yellow foxtail in zones C1 and D1.

Maps of all the islands are given in the original publication, coloured to show the different vegetation zones and phases. The major land uses are shown by means of symbols.

HAWAII: RESEARCH ON FODDER PRODUCTION

Current progress on a number of aspects of fodder production is noted in the Report of the Hawaii Agricultural Experiment Station for 1941 and 1942, published in April, 1943 by the University of Hawaii, Honolulu. With the prospect of partial or complete cessation of imports of animal feed since the beginning of the war between the United States and Japan, the chief interest in the field of agronomic research has been the production of crops locally to provide complete rations for livestock, including more particularly dairy animals, swine and poultry. An important aspect of the whole fodder problem is the preservation of crops by various means to supplement the local practice of utilization in fresh form throughout the year.

Mechanization

Owing to the short supply of labour, there is a great need for the development of agricultural machinery for the mechanization of all phases of production. Research covers wheel-type tractors, two-row planters, two-row cultivator attachments, fertilizer equipment, overhead-irrigation equipment, and the use of a corn binder operated by a power take-off from the tractor in harvesting certain types of forage crops. Maize, sorghum, pigeon peas, koa haole and *Desmanthus* have been effectively cut and bound, while the machine can also be used for cutting Napier grass and Guinea grass, being sufficiently sturdy to cut easily through the very heavy growth. Certain changes in the design of the binder would add appreciably to its effectiveness and adaptability. The cutting of Napier grass and other coarse perennial forage grasses by hand often approximates half the total cost of production, and the cutting of these grasses with the corn binder is expected to be a more rapid and economical process.

Soilage Crops

Artificial Drying: Because of the availability of fresh fodder throughout the year in Hawaii, crops have seldom been dried, but it is considered that present conditions might make this advantageous. Dried surpluses could be preserved; dried crops take less space in storage and shipment, and dried products could be added to local prepared feeds to give them variety. Although air-drying is not possible in zones of moderate and high rainfall, there are areas of dry lowlands with good drying conditions during most of the year.

Instead of importing or constructing driers to handle bulky crops, it is thought that the large, rotary direct-flow driers used in pineapple canneries for producing pineapple bran could be utilized during slack periods. No difficulty was encountered in the drying of an experimental 1-ton lot of freshly cut *Leucaena glauca*; when ground in a hammer mill, the resulting product had the appearance of first-grade lucerne-leaf meal, and had a protein content of 12.72 per cent. It is thought that pigeon peas and *Desmanthus* could be dried in the same way. Experiments are also in progress on the shredding and drying of sweet potatoes, of which surplus and culled crops could be used as feed.

Ensilage. A number of dairymen and ranchers have constructed silos of the erect, metal or wooden type and of the trench type, in order to extend the seasonal availability of certain roughages. If mechanical harvesting with the corn binder becomes an established practice and whole fields are cut in one operation, some

form of conservation such as ensilage becomes essential. Research has begun on the ensiling of the more common types of forages and by-products used for dairy feeding in Hawaii, including Napier grass, *Leucaena glauca*, *Desmanthus*, strip cane and yeast slurry.

Ensilage appears to offer no special difficulties, and the fodder produced is comparable in appearance and quality with that produced elsewhere. The silage prepared had a normal pH range of 3.5 to 4.5. The addition of water was necessary when freshly cut material was used. The addition of molasses was also not essential, but the cheapness of this product made it appropriate to add the maximum amount; 5 per cent of molasses appeared to be the optimum in most trials. When *Leucaena glauca* was added to Napier grass or strip cane in the proportions of 1 : 1 or 1 : 2, the product was considerably more palatable than the Napier grass or strip cane alone. Yeast slurry, added to strip cane to the extent of 15 per cent, increased the protein content of the silage on a dry-matter basis from 2.42 to 4.76 per cent and increased palatability.

Individual Species. Sudan grass (*Sorghum sudanense*) was formerly extensively grown as a soilage crop in Hawaii, but has been largely superseded by the higher-yielding Napier grass (*Pennisetum purpureum*). Were it not for its defects (poor ratooning after the first year and susceptibility to disease during the winter months) many dairymen would prefer it to Napier grass or *Panicum* because of its higher palatability, greater leafiness, and greater nutritive value. An attempt is being made by the Station to develop a disease-resistant, higher-yielding strain on the basis of material introduced from Wisconsin and Texas.

The eyespot disease of Napier grass, caused by a biological strain of *Helminthosporium sacchari* distinct from the strains responsible for eyespot of sugarcane, reached epidemic proportions in Hawaii in December, 1939, with the result that only resistant strains can now be grown. These are based upon hybrids between Napier and Merker grasses, the latter being quite resistant. Strain 34 : 18 appears to be the closest approach to Napier grass in respect to softness of stem. Much remains to be done towards improving agronomic characters, particularly succulence, leafiness, rapidity of ratooning, and adaptation to higher altitudes and to grazing. Plants of the Napier type have been introduced from Uganda, and of the Merker type from Florida.

It is desirable that the Islands should produce good leguminous forages that will replace much of the imported concentrates used in the dairy industry. The increased use of strip cane as carbonaceous roughage should release lands now under Napier grass or other soilage grasses for the production of legumes. The three tropical leguminous shrubs, pigeon peas (*Cajanus indicus*), koa haole (*Leucaena glauca*) and *Desmanthus*, appear to be most promising, all being perennial and well adapted to zones of moderate rainfall, or, when irrigated, to dry zones. They have been used to a considerable extent for grazing, but little is known about their reaction to periodic cutting.

Recent experiments with pigeon peas show that all operations from planting to harvesting and threshing can be readily mechanized. In many respects this is an "all purpose" crop, providing not only seed for animal fodder or human food but also roughage from which a leaf meal may be prepared. Being perennial, a large acreage could serve as a permanent reserve of animal or human food. If not required for soiling purposes, it may be grazed. The effects of cutting are now being studied

(preliminary cutting to induce low branching, height of cutting, spacing, and selection of plant types best adapted to periodic cutting).

Leucaena glauca and *Desmanthus* have been compared as regards their yield when cut periodically for forage. The entire plant was cut off at 4 to 6 in. above ground level at intervals of 2, 3 and 4 months. Ample irrigation was provided but no fertilizer. Fig. 1 shows the yield of dry matter and of protein for the first year.

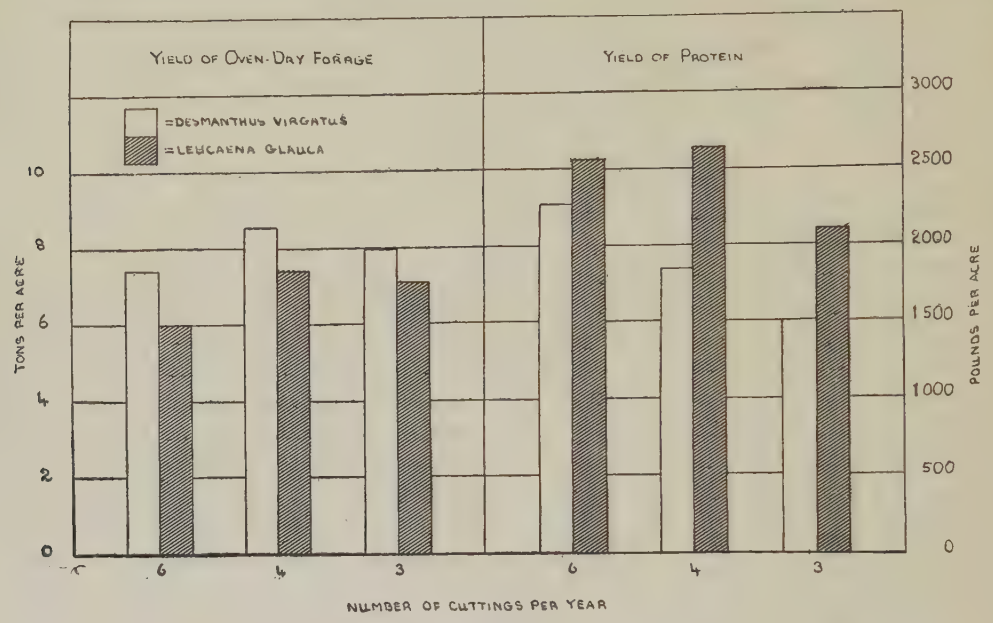

FIG. 1.—Yield of oven-dry forage and protein in *Desmanthus virgatus* and *Leucaena glauca* during the first year.

During the second year, koa haole has shown definite superiority over *Desmanthus* in various yield criteria ; koa haole was higher in yield in the second year than in the first, indicating persistence even under severe cutting. The crop may be cut and harvested with a power-driven corn binder ; the green forage has been dried and ground into meal resembling lucerne meal in appearance and nutritive value. The following agronomic problems are being investigated : height of cutting, length of period from planting to first harvest, growth of plants from direct seeding compared with transplanted seedlings, and response to lime and phosphates.

PASTURE PLANTS

The Station maintains twelve trial gardens placed in each important zone for testing the adaptability of new introductions. It is found that temperature alone restricts certain cool-weather crops such as vetches to high altitudes, and tropical crops such as *Leucaena glauca* to the low altitudes. Many grasses found to be desirable in other parts of the world for their persistence and drought resistance have poor adaptability in Hawaii, while other species not considered important elsewhere are of great value in Hawaii.

Grasses are too frequently judged by their total production of forage, an unreliable basis for robust species which develop a large proportion of stem as the plant matures. Under grazing conditions, the mature stem is almost entirely wasted and, even as a chopped forage, large amounts of stem reduce the palatability and nutritive value. In order to obtain a better comparative estimate of the characteristics of different varieties of Napier grass (*Pennisetum purpureum*) and Guinea grass (*Panicum maximum*), the green leaves and immature stem portions were separated from the mature stems and dry leaves at various stages of maturity and the percentage of each determined. The variation between strains is shown in Fig. 2.

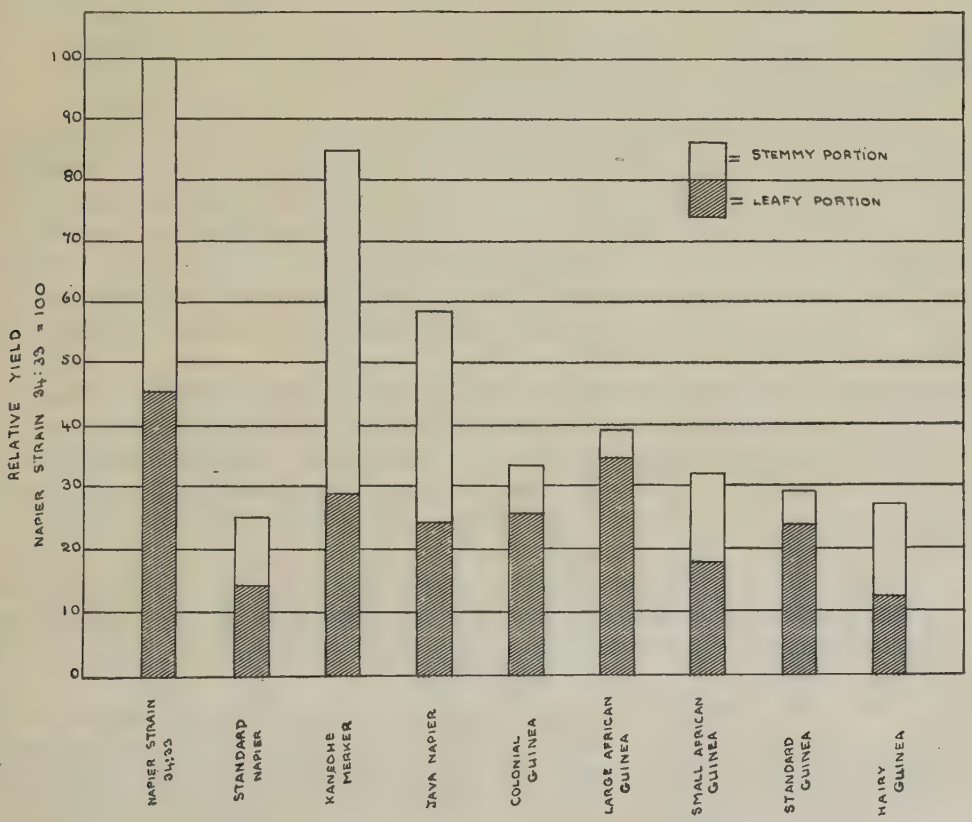

FIG. 2.—Relation of green leafy portion to total yield of different strains of Napier and Guinea grasses. (Green forage yield of Napier hybrid Strain 34 : 33 taken as 100).

INTRODUCED PASTURE SPECIES. The Station is at present observing the following species, which show promise but have not yet been sufficiently proved to justify distribution.

Brachiaria brizantha, introduced from Texas. This has a semi-erect growth habit; its leaves are abundant and dark green, but rather harsh. It remained green at the Poamoho Branch Station when most other grasses had dried up, and it grew well as high as 2,200 feet at the Haleakala Branch Station. It is now being tested for palatability.

Panicum coloratum (Kifuta grass), introduced from Kenya. This grass has a

rather hard stem, but is more leafy than a similar species, *P. prolutum*. It is apparently quite drought-resistant and has grown well from sea level to 4,000 feet. Its yield and persistence are now under test.

Paspalum malacophyllum, native of Bolivia and Brazil, introduced from Georgia. This is a soft-stemmed, leafy grass that yields well but is only moderately palatable. It produces an abundance of viable seed ; consequently a grower may readily develop his own seed supply. Its persistence under grazing is now being determined.

Indigofera endecaphylla, introduced from Ceylon. This legume has prostrate stems, and covers the ground rapidly when once established. It has grown exceptionally well at Haleakala under grazing conditions and has persisted under very dry conditions at Poamoho. Its principal use elsewhere is as a green manuring crop, although several investigators have reported that it also has good forage value. Its desirability as a forage is being tested further.

Desmodium canum. This legume resembles ordinary Spanish clover (*D. uncinatum*) but has smaller, more reddish flowers and more ovate leaves. When grazed, it develops prostrate stems that root at the nodes. Evidently it has been in the Territory for some time, as it occurs at numerous localities on Kauai, Oahu, Hawaii, and probably on the other islands. It is a prominent part of the pasture sward at the Kaimi Farm on Oahu, where it has persisted well under grazing. If further investigations bear out early promise, this legume should be particularly welcome because it is adapted to the wet D_1 zone, which is almost devoid of good leguminous forage species.

D. canum has excellent seeding ability. Plants at the station's Pensacola site produced an average of 44 pods to an inflorescence. Under normal conditions most of the flowers set pods averaging about 5 seeds each. The time from blooming of the plant to maturity of the seed was 12 to 19 days, depending on weather conditions. A 90–foot row produced a total of 42 ounces of seed in the first 6 months of growth.

Lotus angustissimus, introduced from Auckland, New Zealand. Though closely resembling birdsfoot trefoil (*L. corniculatus*), this legume appears to be much more vigorous and has made a strong growth in the very wet D_2 zone. Its persistence under grazing has yet to be determined.

Persistence of Pasture Species. As temporary pastures are of little importance in Hawaii, the species to be sown when a new pasture is being laid down must persist over a long period. The persistence and grazing value of a number of grasses and legumes are therefore being determined. The following tentative conclusions are made at the end of the third grazing period.

Of sixty-seven species planted, only twelve grasses and four legumes were present in such amounts or showed such increase in stand that they could be expected to persist. Of these, only seven grasses and three legumes can be recommended for pastures ; they are : *Digitaria pentzii*, *D. milanjiana*, *Pennisetum clandestinum* (Kikuyu), *Cynodon dactylon* (Bermuda), *Paspalum dilatatum*, *Tricholaena repens* (Natal redtop), *Desmodium tortuosum* (Florida beggarweed), *Desmodium canum* and *Indigofera endecaphylla*.

Other grasses, such as certain species of *Andropogon*, are well adapted to this location but tend to become stemmy and provide comparatively little grazeable forage. These grasses may, however, be acceptable for low, dry zones where better species are not adapted.

Systematic measurement of changes in stand and in rate of spread of nine aggressive creeping grasses showed that certain species, such as *D. milanjiana*, were very persistent but had low powers of invasion into stands of other species. Others such as panicum grass (*Panicum purpurascens*) had strong powers of invasion but weak persistence in their own plots. Kikuyu grass had both persistence and power of invasion.

Carrying capacity for the various paddocks may be expressed in acres required per cow per year, as follows: Kikuyu grass basic, 1.47 acres; *D. pentzii* basic, 1.23 acres; Bermuda grass basic, 1.49 acres; and molasses grass basic, 1.08 acres. The *D. pentzii* paddock was the most desirable from many standpoints and is being continued in order to measure further changes in plant population. The high carrying capacity of the molasses grass paddock was not due to this species but to the volunteer species which produced a fine grass mixture in the first 2 years.

The molasses grass, Bermuda grass, and Kikuyu grass paddocks have been ploughed and planted to single species or simple mixtures for grazing trials. To determine whether Napier and Merker grasses will persist in competition with Kikuyu, Napier hybrid 34:18 was planted in one half of the Kikuyu grass paddock and Merker grass in the other.

Pastures are seldom fertilized in Hawaii, but evidence has been obtained of substantial response to both nitrogen and phosphoric acid when applied to Kikuyu grass in a locality with a rainfall of about 70 in. annually.

Pasture Legumes. This is an important pasture problem in Hawaii; because of the great diversity of climate and soils, there is a need for pasture legumes adapted to each type. The following statement indicates the legumes at present established in pastures and found to be of value as forage; although this appears to be a very favourable position, the proportion of pastures in the Territory that actually contain desirable legumes is small.

Zones A and B, low to medium altitude and rainfall: algaroba, koa haole, desmanthus. (The first is a tree, the other two are shrubs.)

Zones B and C, low to medium altitude and rainfall: koa haole, Spanish clover, pigeon peas, and the winter annuals, bur clover, black medic, and Indian yellow sweet clover.

Zones D_1 and D_2, low to medium altitude and high rainfall: good leguminous forage seldom present.

Zones D_3 and E_1, high altitude (above 3,500 feet): white clover and hop clover in areas of high rainfall, and vetch, bur clover, and black medic where the rainfall is lower and more seasonal.

The ecological factors that govern the distribution of the pasture legumes are now being investigated by mapping the present distribution and relative abundance of thirty-six important species. The vegetation zones previously described are helpful, but it is apparent that for raising legumes a knowledge of localized factors of climate and soil is necessary. Twenty legumes most likely to be adapted were planted in four different zones, ranging in rainfall from 40 to 100 inches per annum, and in altitude from 1,200 to 6,000 feet. At each location the planted rows were cross-stripped with lime and phosphates. Parts of each plot of each legume were treated with the appropriate nodule inoculum. Preliminary results indicate that fertilization may be very important in establishing legumes in pastures.

Kaimi Spanish clover (*Desmodium uncinatum*) is regarded as of possible importance

in wet, lowland pastures. The growth habits of the plant in pastures, in cultivated plots, and in special boxes constructed for determining root distribution have been observed. It has a large root system, but the roots are shallow and the tap root very short, indicating that the plant may be susceptible to drought. When uncut, the plant develops strong, upright stems with elliptical leaflets resembling those of ordinary Spanish clover. When the plant is cut or trampled, a strong growth of decumbent or prostrate stems develops, and this growth roots at the nodes. The leaflets on this type of stem are small and rounded, so that at a distance the plant resembles white clover. By means of these decumbent stems the plant spreads rapidly ; a single plant in a pasture sometimes attains a spread of 15 feet or more in a few seasons.

Roughage for Dairy Cattle

Reference to the roughages that can be used for dairy cattle in Hawaii is made by L. A. Henke in Bull. 92 of the Agricultural Experiment Station. The following grasses and legumes were studied with respect to their growth habits, yields on a green and dry matter basis, palatability, chemical composition, and effect on milk production : *Medicago sativa, Desmanthus virgatus,* pigeon pea (*Cajanus cajan*), koa haole (*Leucaena glauca*), Guinea grass (*Panicum maximum*), Mexican grass (*Ixophorus unisetus*), Napier grass (*Pennisetum purpureum*), panicum grass (*Panicum purpurascens*), Rhodes grass (*Chloris gayana*), and Sudan grass (*Sorghum sudanense*).

Sudan grass was more palatable than Napier grass, panicum and Rhodes grass, and it resulted in higher milk production than was obtained when the other three grasses were eaten. Guinea and Napier grasses were approximately equal in palatability and milk production. Mexican grass was more palatable and produced more milk than Napier grass. Yield data on the leguminous roughages tested show that green pigeon pea tops, at an assumed yield of 25 tons, supplied the greatest quantity of digestible protein per acre. Of the non-legumes, panicum was highest in protein yield per acre followed by Mexican grass and Sudan grass. On a monetary basis pigeon pea appears to be the most valuable leguminous roughage and panicum and Napier grass (which excelled in total yields) the most valuable non-leguminous roughages.

Seed Studies

Very low germination of seed of *Leucaena glauca* is experienced when this forage crop is sown by ranchers. Dormancy or delayed germination is due to the presence of a very thick, many-layered seed coat which hinders the absorption of water by the seeds. Germination is increased only by treatments which alter the nature of this impervious seed coat ; the best treatment are mechanical scarfication in a revolving container in which the seeds are subjected to the abrasive surface of the inside wall, and the soaking of the seeds for from 1 to 2 hours in a 52 per cent sulphuric acid solution.

Low germination is also a serious problem with forage grass seeds. The causes of dormancy or delayed germination of the seeds of eight grass species have been determined and methods to break the dormancy developed. The following conclusions were drawn after a study of various chemical and physical treatments.

Germination of the seeds of *Sporobolus wrightii* and *Panicum prolutum* is hindered by the nature of the seed coats, which prevents an adequate gas exchange

(oxygen intake and carbon-dioxide output) through the seed coats. Altering the seed coats by soaking the seeds in water, cutting the seed coats, scarifying with concentrated sulphuric acid, or subjecting the seeds to daily alternating temperatures promotes the necessary gas exchange in the process of respiration and thus increases germination.

Germination of the seeds of *Sporobolus airoides*, *Poa pratensis*, *Cynodon dactylon*, and *Pennisetum setosum* is hindered partly by the nature of the seed coats and partly by lack of some internal respiratory and perhaps nutritive stimulus. Alteration of the seed coats by the above methods improves germination. When respiratory stimulants like ammonium thiocyanate and vitamin C are given to seeds of *Pennisetum setosum*, germination is increased. Germination of *Sporobolus airoides* seeds is also favourably affected by vitamin C. Potassium nitrate improves germination of all four of these species, the role of the chemical being one of respiratory stimulus or perhaps one of nutritive stimulus.

The cause of low germination in the seeds of *Paspalum notatum* is the presence of tough hulls which enclose the caryopses and prevent maximum expansion of the embryos. Acid scarification, or removal of the hulls, increases germination. Poor germination of the seeds of *Pennisetum ciliare* is due partly to secretion of an inhibitor by the hulls, and partly to the gas-impervious nature of the seed coats. The removal of the source of the inhibitor or adsorption of the inhibitor by charcoal or soil particles causes improved germination. Altering the seed coats is also of benefit.—R. O. Whyte.

FIJI: PASTURE TYPES AND MANAGEMENT

During the development of the pastoral industry in Fiji and, more recently, since the development of dairying, much information of a practical kind has been gained in regard to pasture management. There are many dairy farmers and stock raisers who do little towards the improvement of their pastures and even on the better managed properties much remains to be done. The need for more thought and greater effort in pasture improvement is stressed in order that animal production and dairying in particular in this country may be brought up to the full productive capacity of the land.

Experience on which the development of pastures in this country was based in the early days was that gained almost entirely in pasture management in temperate zones.

The importation and introduction of most of the well-known pastoral plants of temperate countries have been attempted but with little success. With the exception of *Paspalum dilatatum* and couch grass, *Cynodon dactylon*, imported grasses from such regions have not thrived, and it is necessary to turn to other tropical zones to obtain pasture plants suitable to the climatic conditions of Fiji. Whereas considerable expense has been incurred and care exercised in attempts to introduce plants of temperate zones, many of the existing pasture plants have been accidentally introduced by the immigration of people or by mixture amongst seeds of vegetables and other introduced plants. The deliberate introduction of Para grass (*Brachiaria mutica*) is an exception.

There are very few indigenous grasses in Fiji. Before European immigration occurred, it appears that land not covered by forest was covered mostly by the tall grass, *Miscanthus japonica*, commonly called a reed. There were few other grasses of importance present. One often hears the expression that a pasture in a certain field 'consisted of native grasses.' This statement is erroneous. What is really meant is that the grasses are of natural occurrence. As indicated above, most of the grasses growing in any field have been imported.

Any attempt to improve pastures should be preceded by a well-planned fencing programme. Good fences are necessary to control the grazing of the pastures. Where grassland is already in existence, its improvement should be carried out in the following order:—the elimination of weeds, drainage and the improvement of fertility status. It is considered that the eradication of weeds and the consequent encouragement of uniform grazing is a most important operation in effecting improvement. In this connexion much greater use should be made of some form of grass-cutting machine.

The dairying lands in the Colony require more drainage and better control in the maintenance of drains. When the pasture has been improved by the elimination of weeds and by draining, considerable improvement of the nutritive qualities of the pasture is to be expected from the judicious use of artificial fertilizers or of farmyard manure.

Most soils are deficient in lime, and dressing with one of the more easily available forms of lime is advantageous. Interest seems to be awakening to this fact, and it

is hoped that in the near future agricultural lime will be available at a reasonable cost. Coral sand is useful (90–95 per cent calcium carbonate) and is occasionally applied.

In many cases in lowland pastures it is necessary to resort to the plough to bring about effective and rapid improvement of pasture. This is more particularly noticeable when it is desired to re-establish good Para grass fields.

Robinson and Pierre of the United States show that lime, together with a dressing of nitrogen, phosphorus and potash, increase the desirable plants in the sward. Lime and phosphorus increase the yield anything between 37 to 87 per cent while all the above fertilizers, together with lime, gave increase as high as 227 per cent.

In Fiji preliminary pasture experiments in the wet zone, initiated just before the war, indicated that pastures were quickly and substantially stimulated by top-dressings of coral sand, materially improved by dressings of lime, and slightly improved by dressings of bat guano and of superphosphate. It is considered, however, that the latter two fertilizers were unable to exercise their full effects owing to the primary need for lime in the soils on which the observations were conducted, as indicated by soil analyses (1). The observations definitely showed beneficial results from the use of coral sand, which is readily available but which has so far been little used.

Similar observations in the dry zone, in connexion with sheep nutrition experiments, indicated that dressings of 320 lb. per acre of Shirley's Compound (NPK), basic slag and superphosphate, each stimulated remarkable improvement of the pasture not only in volume but in growth of *Desmodium* and in its ability to continue through the drought period of the year (2).

The botanical composition of the herbage materially affects the response to fertilizers. The legumes, in particular, respond to the application of lime and phosphorus, while nitrogen produces an abundant fresh leaf in grass.

In the wet zone of Fiji, there are two types of dairy farm land, alluvial river flats and hill land. In the former type free use of the plough is indicated, while in the latter, owing to the risk of soil erosion, the use of ploughing is hazardous. In bringing about rapid improvement of the pastures on tillable land, ploughing should be adopted after the erection of fences and construction of drains. Cultivation should be done after light to moderate rains. A fair proportion, at least, of the available pasture land should be put down to Para grass. This grass may be established in newly ploughed land by laying cut stalks in the furrows so that a portion of the stalks will not be covered by the turnover of the next furrow. Unless such a field is cross-harrowed, it will be found uncomfortable to the cattle and the field workers owing to the rough surface of the ground. Harrowing should, therefore, be done in the early stages.

Some cultivation of alluvial flat pasture land should take place on each farm annually. If a Para field has been in use for several years and subjected to considerable grazing, it will be found that other plants occur more and more frequently in the field, until the sward becomes very mixed. This may be considered as more or less desirable, provided that new fields are prepared and laid down to Para in rotation.

It may be well at this stage to give details of a scheme for the control of grazing on dairy farms where the fields consist of Para alone in some fields and mixed herbage in others. There is no doubt as to the high value of young Para grass as a principal feed for dairy cattle and every effort should be made to obtain the greatest benefit from these fields, and at the same time to conserve their usefulness. Much damage is done to Para grass by allowing cattle to remain too long in the fields so that much of

the Para is destroyed by excessive tramping and by cattle lying down after feeding. It has been found a good plan to place the cattle immediately after the morning's milking in the Para field to be grazed. Cattle will feed eagerly at this period. They should be carefully observed and when it is seen that they have eaten their fill and are commencing to lie down, they should be driven out of the Para field into one of short pasture, preferably where shade is provided and on a river bank, if possible. The time of this first grazing may be as long as 2 hours. The same procedure may be adopted following the afternoon milking, after which the cattle are again moved to short pasture for the night.

When the grazing lands of a dairy farm in the wet zone consist of a mixture of flat and hillside land, the flat land should be devoted to the growing of Para grass and the hillside land to shorter, mixed pasture. Alternation of flat and hillside grazing should be carried out as described above. It will be found that improvement of hillside grazing will be best carried out by the removal of roughage, weeding and by the use of manures.

When cattle are grazed on coconut plantations it is necessary to modify the method of pasture management, owing to the presence of the trees. When the trees are well spaced a sufficient amount of sunlight filters through the tree-tops to provide for normal grass growth. In fact, the amount of shade provided is beneficial to some grasses. The use of cultivation implements on many plantations is impracticable. If the land is free of rocks and logs a form of rake to remove fallen coconut leaves and other debris assists greatly in keeping pastures clean. This operation may be followed by the use of a grass-mowing machine. Needless to say, the plantation grazing area should be kept clean from weeds. Rotational grazing is just as essential in grazing in coconut groves as on other types of land.

Pasture management in the dry zone presents quite a different problem. As on other lands, boundary and sub-division fencing is required for proper management. Over most of the areas, the provision of a large amount of draining is unnecessary. Methods of pasture control must be devised to suit the particular incidence of rainfall which occurs in the dry zone.

What usually happens is that the heavy rainfall and the warm humid conditions which exist during the wet season cause abundant and rapid growth of grass. The rate of growth is usually far greater than can be utilized by grazing stock. The result is that towards the end of the wet season the pasture is long, the plants approach the ripe stage and are heavy with seed. Their texture becomes more and more fibrous and their nutritive qualities are lowered in proportion. The dry season is commenced therefore at a disadvantage from the point of view of the quality of the grazing available.

In an attempt to remedy this undesirable condition of the pasture, it is often burned. Should rain not fall after firing, there may be an absolute lack of pasture on the burnt area at the commencement of the dry season. When burning pasture, therefore, one should act before the end of the wet season and endeavour to catch a short dry spell while still anticipating more rain. At this time the soil at the base of the long grass should still be damp. The humus in the soil will be least damaged if such a period is chosen, and the response to the fall of further rain will be rapid.

Many arguments are put for and against the practice of burning grass-covered lands. Arguments in its favour are that the control of noxious weeds is accomplished and, secondly, that old grass is removed allowing for a new flush of grass to come after

rain. Against the practice is the impoverishment of the soil and the grave danger of soil erosion which may follow burning. The humus in the soil resulting from the growth and decay of plant matter is essential for high soil fertility. Most of the humus in uncultivated land is in the surface soil. Excessive burning destroys this humus, thereby lowering soil fertility. If burning is necessary for the control of noxious weeds, in addition to the above-mentioned precautions the intervals between firing should be increased, but it should be borne in mind that all the advantages of firing are obtained by cutting the grass and eliminating the weeds without any danger of serious soil erosion which has already damaged many areas of grazing land.

In order to overcome the difficulty of the existence in the pasture of long, dry, non-nutritive grass at the commencement of the dry season, skilful pasture control is necessary if burning is not practised. The best solution appears to be the heavy stocking of the good lands, on which dry season feeding will depend, just before the close of the wet season. If the land is suitable for the use of a mowing machine, this implement should be used at about the same period. If the grass can be brought into a close, evenly grazed state just prior to the close of the wet season, a flush of young, nutritious grass should come away to carry the stock on through the dry season.

As is to be expected, there is considerable variation in the average composition of pastures according to rainfall and temperature differences due to geographical location. There is also much poor pasture due, not only to poorness of soil conditions, but also to heavy weed growth even when the soil is good and to gross overstocking, especially in the dry zones.

One seldom observes pure stands of any grass. Such do occur, however, in the wet zone in the case of Para grass (*Brachiaria mutica*) and Guinea grass, (*Panicum maximum*), which are lightly stocked or not stocked at all. Grasses of the blue grass family, *Dichanthium* species, are becoming more prominent and small fields of pure stands are to be seen in the vicinity of Suva. In the dry zone the best example of a practically pure stand is Caboni grass, *Amphilophis glabra*, where it occurs on the northern coast of Viti Levu.

In most pastures a particular grass or forage plant will be found to be dominant ; nevertheless, many other species of grasses and weeds may be found in the same field. Among the dominant species found may be mentioned *Paspalum dilatatum*, Guinea grass, carpet grass (*Axonopus affinis*), Thurston, or Sour grass (*Trichachne insularis*), *Paspalum conjugatum* ; the sensitive plant, *Mimosa pudica* ; love or seed grass, *Chrysopogon aciculatus* ; blue grasses (Nadi or Nawai or Mololo grass) *Dichanthium* species, and Caboni grass, *Amphilophis glabra*. One should not fail to mention also the " reed grass", *Miscanthus japonica*, which is indigenous to Fiji and which covers all lands not forested provided it is not interfered with by man or animals through firing, cutting or grazing.

The less prominent species composing the pasture are also important since they help to balance the diet. Of considerable value in this respect are the so-called Fiji trefoils—members of the genus *Desmodium* of which four species occur, namely, *D. triflorum, D. heterophyllum, D. heterocarpum* and *D. polycarpum*. These plants together with the sensitive plant, take the place of the clovers and trefoils of temperate lands.

Among the secondary grasses may be mentioned couch grass, *Cynodon dactylon* ; false Thurston grass, *Brachiaria distachya* ; barnyard millet, *Panicum crus-galli* and *P. colonum*.

In most of Fiji good natural pastures can be maintained and are well utilized but there is wide scope for the general adoption of common methods of pasture improvement and for more attention to the rotation of pastures by graziers and by dairy farmers for their ultimate advantage. Hence, it is hoped that labour conditions after the war may enable all stock owners to tackle these obvious tasks and so profit by the general improvement in the pastures. It is also hoped that it may be possible to re-establish pasture experiments and augment them in several main areas in the near future as war recedes from the Colony.

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GOLD COAST: AGRICULTURAL PROGRESS

A review of progress in agriculture of the Gold Coast to the end of 1942 is given by the Director of Agriculture in the *Empire Journal of Experimental Agriculture*, Vol. 12. pp. 82–102. 1944. The following data are extracted from the review.

The Gold Coast consists of nearly 59 million acres with a population of about 3.6 millions. The three main climatic and vegetative regions are the Northern Savanna of 36 million acres, the closed Forest Area of 17 million acres in which all the cocoa is grown, and the Coastal Savanna of not more than 6 million acres. Practically the whole country is suitable for agriculture, but a considerable area in forest is necessary to protect the cultivation of tropical plantation crops. The population is increasing by 15 per cent in a decade, and the land could support a population at least four times greater than the present.

Several systems of farming have been adopted by African farmers in the savanna areas. In North Mamprussi the farmers live in scattered compounds and cultivate intensively the land round their dwellings. In thinly populated areas, such as Dagomba, they live in compact villages and practise shifting cultivation under which a piece of land is farmed for 2–4 years and then left fallow for 6 years or so. In parts of Keta district the land is fallowed in rotation.

In all the systems, although cattle are available and often owned by the farmer, little use is made of them on the farm. Experiments at Zuarungu and Tamale have shown that systems of 'mixed farming' are better than the native methods in almost every way, raising fertility and giving higher yields. Its extension to other areas is proceeding gradually. In savanna areas mixed farming is the best method by which famine can be overcome, nutrition improved, erosion prevented, fertility improved, surplus food produced for sale, and a firm foundation laid for a sound rural economy.

The management of pastures and temporary leys, the use of fenced paddocks, the use of supplementary feed and fodder in the dry season and the control of soil wash in the ploughed fields are among the improvements to be effected. Root crops for food and leys of legumes and grass have great possibilities. The object is to discover how an improved practice can be incorporated into the local system of farming in a way that will appeal to the farmer.

In the Northern Territories grass burning is regulated or prohibited by rules enforced by the Native Authorities. The beneficial results are to be seen in the improved grass sward.

In the closed forest area the prevalence of tsetse fly has rendered the keeping of cattle unprofitable. The farmers live in villages or towns, and the production of cocoa is their chief pursuit. The local food supply is supplemented by importations from food-producing areas and from overseas. Forest crops, such as plantains and cocoyams, and arable crops like maize, peas, and cassava are grown on young cocoa farms or under shifting cultivation. In either case the land does not remain cultivated long but reverts to trees or secondary bush. It is probable that in the closed forest area some form of shifting agriculture will remain the mainstay of native arable farming. Sir Frank Stockdale has written that it should be the aim of all agriculturists in the wet tropics to maintain or to reproduce as far as is practicable

the conditions which prevail when the land is under forest cover, and that where the conditions are not suitable for the marriage of animal husbandry with crop production, the latter must proceed along lines which conform with the dictates of nature. This is endorsed by experience in the Gold Coast. Shifting cultivation is the best system of crop farming for the wet forest area and is to be preferred to continuous arable cropping. It becomes a menace when pressure of population necessitates greater food-crop production and an inadequate period for regeneration under forest cover. Research on the subject must consider the manurial value of sheep and other small live stock, composting, and green manuring, not only to keep the land longer in cultivation but to reduce the fallowing period.

In the savanna areas there are large tracts where the population is scanty and the land undeveloped. Annual fires sweep over them causing soil erosion, fertility-exhaustion, and deterioration of the vegetation : some areas are so denuded that the land cannot be reclaimed for farming. Some consider that the loss is so great that measures to prohibit burning would be justified. The development of an area with fire-breaks and shelter-belts might prove to be beneficial. Surveys and research would determine the advisability and practicability of such measures.

On the farm the best method of preventing erosion is to use good farming practices ; on wild grazing land, to prevent fires and so encourage a good vegetative cover. Soil erosion is also caused by roads and drains, and the adoption of soil-conservation measures is necessary. There is no overstocking by cattle at present, but, where an increasing cattle population enjoys uncontrolled communal grazing, measures should be adopted to control grazing before soil erosion becomes serious.

GOLD COAST : GRASS IN THE ECONOMY OF THE NORTHERN TERRITORIES

Introduction

Grass is the natural ground cover of the Northern Territories. It is accepted by the people as a source of roofing material, mats, hats, baskets, and shelters, as food for livestock, salt for soup, alkali for soap making, and the seeds of some species are used for human consumption in famine years. Grass is not yet regarded as a crop by the farmers of the Protectorate, and until recently no effort was made to control or to conserve it. Because livestock are reared mainly for uneconomic purposes—sacrifices and dowries—it is unlikely that the native attitude to grass will change until farming becomes less of a custom and more of a business ; there are signs of such an economic awakening. By far the greatest local value of grass is in soil protection, both directly as a ground cover and indirectly as a source of fertility. Critical research on the subject is practically an untouched field in the Northern Territories ; even the identification of species is by no means complete. Sufficient knowledge has, however, been gained from observation trials for the Government to formulate a policy with regard to early burning in some areas, the prohibition of burning in others, and the utilization of grass as fodder and bedding for manure making as integral parts of its mixed farming policy. A brief description of the Northern Territories and the position of grass in the scheme of things are discussed below.

Description of Area

The Northern Territories Protectorate covers an area of 43,000 square miles, roughly square in shape, situated between 8 degrees and 11 degrees North latitude at an average height of 600 feet above sea level. It is contained entirely within the Park Savannah belt which lies between the Dry Deciduous Forest in the South and the Desert Scrub in the North. The country is undulating and drained by innumerable gullies and streams linking up with the Volta River which runs through the Territory. Much of the country becomes waterlogged during the rains and waterless in the dry season.

Climate

Climatically, the area comes within the Sudanese Zone. The rainfall averages 43 inches a year, which fall almost entirely during the 7-month period, April—October; tornadoes mark the beginning and close of the rainy season. The onset of the dry season is very sudden; a hot dry wind, the harmattan, blows from early November to early February, desiccating all before it. During this period, the average relative humidity at 9 a.m. is 40 per cent, and readings as low as 22 per cent have been recorded. Shade temperatures range from a minimum of 60° up to 110° Fahrenheit; extremes are experienced in the dry season.

Population

The distribution of population and livestock in relation to the geological formation of the Protectorate is fundamentally important. Of the total population of over one million people, 36 per cent live upon Voltain sandstone and shale which covers 75 per cent of the total area—an average density of 10 persons per square mile. The remaining 64 per cent of the population is crowded into a narrow strip of granite and greenstone in the North and West, with an average density exceeding 100 persons per square mile. The people of the Northern Territories are primitive pagans; only comparatively recently have they started to become in any way money-conscious. They are all agriculturists following traditional methods on a subsistence basis. There are no nomadic tribes.

Livestock

The livestock of the Protectorate are estimated to number approximately 200,000 cattle, 800,000 sheep and goats, numerous donkeys, a few horses, and a large number of fowls and guinea-fowls. These are owned by the cultivators of the soil, and distributed according to the population. Although numbers are by no means equally divided amongst families, nearly all families own some livestock, and there is a constant circulation for dowries. Surplus livestock find a ready sale to butchers' agents for consumption in the rich mining and cocoa areas in Ashanti and the Colony, and this trade is increasing. Nevertheless, the main reason for raising stock is for the fulfilment of native customs and very little attention is paid to breeding and feeding. The cattle population is increasing steadily as a result of the Government's rinderpest immunization policy, and the improvement of water supplies is of the greatest benefit to all classes of stock. The tse-tse fly infests large areas of the Protectorate, but local stock appear to have a degree of resistance to trypanosomiasis.

Grass Economy in Sandstone Areas

On sandstone, people live in village communities and follow an extensive system of shifting cultivation on the basis of 2 or 4 years' cropping and 5 to 10 years' fallow. Except around the one or two larger towns, there is an abundance of bush land sufficient to allow for an adequate fallow period, and the large proportion of fallow land provides protection against soil erosion. Abandoned fields quickly revert to 'bush' again, and eventually become covered with thick tufts of perennial grasses typified by *Andropogon* spp. In wet places, dense stands of spear grass (*Imperata cylindrica*) appear. Such grasses are used by the farmers as indicators of soil fertility. Annual grasses (*Pennisetum, Eragrostis, Cenchrus, Brachiaria, Digitaria, Eleusine, Chloris, Urochloa*) are found in the cleared areas around villages, and on compound farms. Cattle are herded in the bush to graze and browse in the rains, and allowed open range over the stubbles in the dry season. Sheep and goats pick up a living around the villages. Enclosure is unknown and breeding control and grassland management are not attempted.

Sparse dry season water supplies have kept the population thin and scattered and the grassland comparatively rich and abundant. Cattle from some villages have to be sent away to the Volta river in the height of the dry weather. Such a small proportion of the grass is used and so tall do the grasses grow in the rains, that it is not surprising that the people should keep the country open by annually burning the 'bush.' It is Government's policy to encourage as early a burn as possible after the cessation of the rains, with the object of reducing damage to trees, and leaving a reasonable proportion of litter unburnt for soil protection. Fresh leaves quickly appear on the old tufts of grass after an early burn but the bright green appearance belies the stock carrying capacity, which is very low.

Burning is seldom carried out as early as desirable, because of late crops unharvested in bush farms, and the desire of the people to reserve patches of bush for hunting later in the season. Where water supplies have been improved, as in some of the more important towns, there is a tendency for the people to move into villages near the towns. In these suburban areas the quality of grassland is deteriorating rapidly, the fallow period is gradually being reduced and crop yields are shrinking: signs of sheet and gully erosion are to be found as the soil becomes over-worked and grass becomes trampled out. It is in these areas particularly that mixed farming has an immediate part to play. Observation trials are in progress at the Government Experiment Station at Tamale, the Native Administration Stock Farm at Yendi, and the Veterinary Headquarters at Pong Tamale. The main results from this work so far are:—

1. After 10 years' protection from fire, there appear to be no disadvantages and many advantages. The land does not become choked with undecayed matter and there is an appreciable improvement in ground cover and stock carrying capacity.
2. Hay made from bush grasses, plus what grazing can be picked up, will keep store stock thriving through the dry season, provided water is adequate.
3. Bush grass makes excellent litter for bedding livestock, and the application of the farmyard manure so made, even in dressings as low as 4 tons per acre, will greatly enhance crop yields, and provides an alternative to shifting cultivation.

There are indications that the ideal farming system in sandstone country may include temporary grass leys. Experiments are being designed to give evidence on the subject. Land planning schemes must consider contoured filter strips of fallow in arable areas as well as forest reserves and complete fire control in catchment areas.

Grass Economy in Granite Areas

The sudden change in the ways of living of the people as one passes from the sandstone to the granite and greenstone areas is most marked. Although the average density of population is over 100 persons to the square mile, the actual density in inhabited areas approaches 300 to 400 over large communities. People live in scattered compounds and intensively farm the land between with the aid of manure. The system of farming is a 'fixed' one by comparison with the shifting cultivation practised on sandstone, but the methods of farming are not sufficiently intensive to maintain crop yields on the land permanently. After a number of generations of intensive farming, the land becomes completely worked out and whole communities shift out to new areas. There is scarcely an uninhabited area of the Northern belt which does not show traces of past habitation. If uninhabited for many years, perennial grasses such as *Andropogon* spp. may have come in; but more often the scene presented is a dense stand of *Heteropogon contortus* or *Aristida* spp. in a shea orchard (*Butyrospermum parkii*), with an occasional dawa-dawa (*Parkia filicoidea*) or baobab (*Adansonia digitata*); the land is stony and structureless, and an extensive gully system is generally to be found in the valleys. Once land has been reduced to this state, recovery is almost impossible so long as annual burning is permitted.

In inhabited areas, grazing lands are found in wet valleys and on worked-out arable fields, which have been allowed to go back naturally to grass. In the rainy season, these areas develop quite a fair stand of grasses (*Dactyloctenium, Digitaria, Eragrostis, Urochloa, Chloris, Pennisteum, Setaria, Eleusine, Heteropogon, Aristida*), which grow away from the stock in the height of the rains. For 4 months in the year, June and July, and November and December, grazing is adequate; for 3 months, August, September, and October, growth exceeds requirements; for 5 months, January to May, grazing is inadequate. The problem is therefore one of storage. At the beginning of the dry season, much useful forage is picked up on the stubbles. The value of such leguminous fodder as cowpea and groundnut hay is appreciated, particularly by horse owners, and sheep and goat traders. Horse owners may also select certain grasses (particularly *Pennisetum polystachyum*) for feeding green, or chaffed, dried, and stored for the dry season. The cutting of hay for other classes of stock is, however, considered a waste of time. No fields are enclosed and no attempt is made to control grazing. As for regarding grass as a crop, and creating artificial pastures, the idea is completely foreign.

It is fortunate that most valleys contain clay soils which local farmers are unable to work; these support a dense mass of coarse grasses, *Vetiveria nigritana* being especially common, which protect the valleys and help to keep the stock alive through the dry season. In some of the more densely populated areas, however, such valleys are becoming grazed out.

The people are virile grain eaters, but in years of bad rains or locust invasion many suffer from hunger. Large numbers of poultry are reared and exported to the consuming centres in the South, together with sheep, goats, and surplus male cattle.

In return, grain is imported from the sandstone country. Improvements in road communications in recent years have done much to safeguard these areas from famine, but this provides only temporary relief. It will be appreciated that farmers living on a bare subsistence basis are unlikely to respond to an appeal to feed their livestock better until their own food supply is assured.

The introduction of mixed farming gives an opportunity to alter the situation, and by mixed farming is meant here particularly the manufacture and use of farmyard manure. Survey showed that only 12 per cent of the land under cultivation was manured annually. Experiment suggested that if this could be raised to a minimum of 25 per cent, permanent farming could be put on a sound basis ; further, this was possible of achievement if grass bedding was supplied to livestock—cattle, sheep, goats, and donkeys—for the manufacture of farmyard manure.

In 1938, after four years of observation, the Native Administrations were persuaded to pass anti-grass burning rules applied to inhabited areas, and early burning rules for the surrounding uninhabited ' bush.' The successful application of these rules has confounded the pessimists, and non-burning is fast becoming native custom. Although aimed primarily at the prevention of erosion by both wind and water and the conservation of water supplies by checking rapid run-off, the immediate improvement in livestock and the fact that stock could be grazed nearer home were advantages quickly appreciated by the Chiefs and the people.

Now that burning is under control, Government is pursuing a vigorous policy to encourage the utilization of the grass so saved. Sanitarians and road makers have been persuaded of the dangers of clean weeding. The sickle is replacing the hoe, and *Cynodon dactylon*, which does not get out of control under our conditions, is spreading over roadsides and police parade grounds. Trials are in progress with the reclamation of eroded areas with contour banks, pasture furrows on poor grassland, grass filter strips in poor arable land, graded drains in towns and on roadsides, terraces and contour lay-outs in towns protected by grass. The grass in towns is cut by sanitary gangs and used for making compost with septic tank latrine effluent. Dams are being made in valleys, and wells are being sunk throughout the country. All these vital ameliorative measures depend upon the due appreciation of the value and importance of grass and the education of the people a step at a time.

Summary

A brief description of the Northern Territories is given, followed by a discussion of the distribution of population, methods of farming, and the position of grassland in sandstone and granite areas. Some of the problems, and the need for separate grass policies for the sparsely populated sandstone areas, and densely populated granite areas, are emphasized. There is a time lag in the adjustment of primitive traditional farming method to the economic requirements of the present day. In the meantime, soils are becoming exhausted or lost through erosion and the water situation is deteriorating. It is the soil and water conservation value of grass which is of first importance, and this is recognized by the legislation on the control of grass burning passed and successfully enforced by the various Native Authorities. The second step, the utilization of grass as fodder or as litter for manure making, receives attention through Government's mixed farming policy. But unlike the grass burning policy, which affects the whole community and is immediate in its effect, the extension of mixed farming can only be from individual to individual and progress

is bound to be slow, particularly in the early stages. The problem of increasing the tempo of extension work is more one of administration than of agriculture ; relieved of some of this responsibility, we can turn to the investigation of other agricultural problems, foremost among which must be research in grassland management.

GOLD COAST : OBSERVATIONS OF THE VETERINARY SERVICES*

The Station of the Veterinary Services is a large one, on which are maintained about 1,500 head of cattle plus pigs, sheep and poultry. There are 700 acres of arable land growing fodder crops. Until recently it has been necessary to use all the land that was cleared for arable farming, but in recent years about 150 acres of ex-arable land have been laid aside as grass. By dressing the land with pen manure, the natural pasture has been improved. No grass seed is grown in West Africa and the little that has been collected is low in germination. This top-dressing rather than reseeding has been empirically adopted, in order that the results might be observed.

A profuse growth of *Urochloa lata* comes up, accompanied by some *Digitaria debilis*, *Eleusine indica*, etc. This provides very fine grazing pasture from May to mid-August, but these annuals then die off and subsequently, except for scattered plants of the good second-rate annual, *Pennisetum pedicellatum*, the grazing value of the pasture is low. *Pennisetum* is the only late annual of any value and appears in this pasture about the time the early grasses wither.

The information provided includes a list of some fifty grasses and legumes that have been collected around Pong-Tamale, with notes on their fodder values, characteristics and uses. It has been found that the best grass (*Andropogon gayanus*) grows very well from seed. Over 2 acres have been planted and a first-rate germination and good crop obtained. This perennial produces excellent hay and straw. Sufficient seed is now being collected in order that a larger area may be planted. On the other hand, disappointing results were obtained from a 2-acre plot of *Rottboellia exaltata*. The view is expressed that there is ample scope in West Africa for a specialist to study the characteristics and relative merits of the native gramineous and leguminous flora from the pasture aspect.

Fodder trees are widely used in the Northern Territories of the Gold Coast for livestock feed during the long dry season. The species mentioned (to be discussed in more detail in another I.A.B. Joint Publication) include *Afzelia africana*, *Pterocarpus erinaceus*, *Acacia albida*, *Entada sudanica*, *Ficus gnaphalocarpa*, *Pithecolobium saman*, *Celtis integrifolia*, *Crataeva adnaonii*, *Khaya senegalensis*, *Daniellia oliveri*, and *Vitex Cienkouski*. Edible shrubs are rare.

A plant that is spreading at a most alarming rate throughout the Gold Coast and reducing the value of grazing land is star burr (*Acanthospermum hispidum*). This species is also a pest in pasture land in Nigeria. It has been attacked vigorously in Pong-Tamale station, farms and grazing areas, which cover several square miles, and its incidence has been reduced very considerably by continual cutting and pulling before it seeds. This campaign has been very successful and has not been costly.

*Note based upon information provided by J. L. Stewart, Director of Veterinary Services, Gold Coast, in letters dated Sept. 9 and Dec. 4, 1943.

NIGERIA: GRASS FARMING AND GRASSLAND IMPROVEMENT

Frequent references to the position in Nigeria with regard to grassland management and the place of herbage leys in systems of alternate husbandry were made in Joint Publication No. 6 of the Imperial Agricultural Bureaux on "Alternate husbandry." These references were based on published literature from Nigeria and upon memoranda supplied by the Director of Agriculture.

A short summary of progress to date prepared from the letter sent by the Director to the Pasture Bureau in June 1943, may be reproduced here; most of the work to date has probably been done in the Northern Provinces, because of the larger cattle populations, and the initiation of the mixed farming schemes in these Provinces, described fully in Joint Publication No. 6.

(*a*) A study has been made of the local grasses, and many of them have been analysed and their nutritive value ascertained. This work is not complete, but we have sorted out those which are likely to be useful to us and are now concentrating on these.

(*b*) Work on grassland management apart from grass of bush fallows has only just been commenced, but we have done some work on the feeding value of bush grazing, and hay and silage made from bush grasses.

(*c*) Experiments are in progress to test the value of pastures in restoring soil fertility, but these have not gone very far.

(*d*) We have done a great deal of work on forage crops necessary to supplement pastures, and in the Northern Provinces learnt how to maintain the weight of our cattle throughout the dry season. We have, however, not yet found a suitable fodder crop for the very dry areas of the extreme North, except the groundnut.

Northern Provinces

The main problems arising can be conveniently classified under two main heads: —agricultural and pastoral.

Agricultural aspects. Peasant farming is, and is likely to remain the most important industry of Nigeria as a whole. The Northern Provinces pasture a considerable cattle population but, in spite of this, hand tillage is the method of cultivation natural to the farmer. The explanation is that the cattle are owned by the nomadic Fulani and not by the farming Hausas and Pagan tribes. One other striking feature is that the farming community live in towns, villages, and hamlets and are seldom found squatting on their own land. Intertribal strife in the past must be held responsible for this gregarious habit.

Due partly to tribal custom, but more particularly to climatic differences, the crops grown and the rotations followed vary considerably in the various parts of the Northern Provinces, but the general pattern of actual cultivation remains the same.

Immediately surrounding towns and villages, permanent cultivation is the general rule, made possible by annual dressings of household refuse and ashes, and the manure collected from small stock, donkeys and horses, carefully conserved for the purpose. The level of fertility varies with the distance from the town, but in

the inner circle it is often quite remarkable, heavy yields of corn, maize, millet or guinea corn being maintained, it would seem indefinitely, without any rotation of crops.

Outside the immediate vicinity of the towns and villages, a system of shifting cultivation is invariably followed. The farmer clears and cultivates a piece of bush for 4 to 5 years and then abandons it to a fallow of grass for a similar, or longer period of years, when the fertility has become exhausted. In cattle country, the well-to-do may pay the Fulani to kraal their farms with cattle, and fertility may thus be maintained for a longer period than usual, but sooner or later all this class of land returns to bush. Almost all peasant farmers own both types of farmland, the proportion of temporary to permanent being approximately four to one.

During the past decade, a policy of mixed farming for peasant farmers has been pursued by the Agricultural Department and rapid expansion in the numbers adopting this system is anticipated in the post-war period. Financial assistance is given to set up approved men with two working bullocks and a plough. Pen manure is conserved and this, together with the normal household refuse, has been found sufficient to maintain the fertility of an 8 to 10 acre farm.

It is becoming increasingly apparent from our 15 years' experience on our Experimental and Demonstration Farms that a rotational grass ley is highly desirable under all schemes of permanent cropping.

From the point of view of stock alone it is obvious that a bulky yet nutritious hay crop, to supplement dry season grazing and to replace the poor quality hay which can be made from the natural grass herbage, is to be desired. It is becoming increasingly apparent, moreover, that stock should be pastured on the farm, at least at the height of the rains, when the incidence of tsetse is at its height, if trypanosomiasis infection in the communal grazing is to be avoided.

Apart from the maintenance of stock, the need for a grass ley to combat weeds and to help to control plant parasites is becoming recognized.

Certain obnoxious weeds, chief of which are *Imperata cylindrica*, *Cynodon dactylon*, and a stoloniferous *Digitaria*, tend to take possession of farmland under conditions of permanent cultivation, often with disastrous results on crop yields. Similarly, plant parasites may increase rapidly unless the length of the crop rotation is adequate. The best example of this is the local species of *Striga*, which causes much damage to the staple food crops, maize, millet, and guinea corn. Similar difficulties are experienced even under the native system of grass fallowing. In certain of the Northern Provinces, e.g. Benue and Kabba, the pressure on the land of an increasing population has so reduced the grass fallow that the problem of weed pests and soil exhaustion is already acute.

Pastoral aspects. The pastoral problem applies to livestock generally, but more particularly is it a cattle problem. The larger proportion of Nigeria's cattle population (estimated at 4 million head) is managed and owned by the nomadic Fulani. From the point of view of health, experience has shown that conditions are most favourable to stock north of latitude 11.5°N. where sandy soils predominate and the climate verges on the semi-arid. These regions are favoured by the stock owners, and the explanation lies in their comparative freedom from ticks and tsetse.

The low rainfall and the short wet season set a definite limit to the period over which the nomadic herds can be maintained in this belt, and a seasonal southward migration of the larger proportion of the Zebu stock starts about October each

year. Those that remain—a small proportion of milking cows and young calves—maintain fair conditions on waste products of the extensive farm land, groundnut haulms and leaves of millet and guinea corn, rather than on the scanty desiccated herbage.*

The southward migration progresses by easy stages and roughly synchronizes with the cessation of the rains in the moister belts farther south. In the dry season the tsetse retires from its wet season feeding grounds and remains concentrated only around more permanent swamps and all-season streams, so that the incidence of trypanosomiasis is lowest at this time. As the tick population also shows a marked reduction compared to that in the rainy season, again conditions from the point of view of health are optimum. The same cannot be said of the nutritional environment, however, because the quality of the natural grasslands is at its lowest at this time. Even the latest flowering species of the indigenous herbage reach the seeding stage by the end of the rains and natural pastures can then provide only a sufficiency of bulk with an insufficiency of quality. The browsing of trees and shrubs is of considerable importance at this time and supplies a welcome supplement of protein and minerals. The experienced herdsmen resort to bush burning in order to induce a flush of succulent pasture regrowth, but the balance between quality and quantity is so precarious in these hard conditions that it is axiomatic that nomadic cattle lose a considerable proportion of their annual wet season live-weight gains.

The seasonal periods of semi-starvation of the cattle have a serious effect on production, reproduction, and resistance to disease, and it is obvious that no general improvement of nomadic herds can be undertaken until a solution of the nutritional problem has been found.

These briefly are the problems with which grassland research is confronted. The purely farming problems present no insuperable difficulties, but the amelioration of the nutritional environment of the country's livestock is undoubtedly a more difficult task. It is possible that a palliative may be found in the conversion to improved dry-season pastures of the considerable areas of swamp land (evidence of a river system draining towards Lake Chad) that exist in the more northerly provinces. But this can be no more than a palliative.

A solution of the whole problem must entail the conservation and improvement of much of the natural grassland of the Northern Provinces, and the evolution of some form of positive management. The problem too, is closely bound up with the eradication or control of the tsetse fly, which in turn may entail the clearing of much of the country's best timber. Only patient research can remove the prejudices which are inevitable when the interests of the farmer, stockowner and the forester conflict.

The future of the Northern farmer, however, must inevitably be more closely allied to the welfare of the cattle population than has been the case in the past, so that, if the long view is taken, there is a greater identity of interest than may at first sight be apparent.

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*8.5° to 9°N. is the approximate limit of the southward movement of cattle, but it must not be imagined that migrations start from the northern limits. North of latitude 9 to 9.5° is generally considered all-season country and numerous herds remain in the 9 to 11.5 belt throughout the year. The southward seasonal migration is, however, general throughout the Northern Province, the return in the opposite direction taking place with the onset of the next wet season.

Outline of Research Programme. Preliminary proposals to establish a post-war main Grassland Research Station and at least one sub-station in the Northern Provinces are under consideration by the Agricultural Department. The scope of these proposals has been summarized as follows :—

(*a*) Research will be initiated into the management and improvement of natural grassland with special reference to carrying capacity, annual burning, ecological successions, the balance between timber and grass, timber and tsetse, and allied nutritional problems such as browsing and the mineral and protein intake of cattle.

(*b*) Research will be conducted into the desirability of incorporating temporary grass leys into the arable rotation of peasant farmers with special reference to the anticipated steady progress towards a more universal practice of mixed farming.

(*c*) Research will be conducted into the suitability of local and exotic species with regard to specialized requirements such as artificial pastures, aerodrome runways, soil conservation, etc.

(*d*) The problem of live fences for stock will also be investigated.

A number of local grasses and also a number of species introduced from South Africa are under examination now to ascertain their usefulness for cut fodder or pasture purposes.

Southern Provinces

While the difficulties due to the dry season are not quite so acute in the South as in the North, the production of good dry season fodder is still one of the main considerations. The matters requiring investigation are the same, generally speaking, as in other tropical areas, and in brief are :—

(*a*) the production of a regular supply of nutritious herbage throughout the year, with special attention to the maintenance of soil fertility to ensure future production. Closely connected with the latter is the determination of the feeding values of the main indigenous herbage plants at all seasons of the year, and also of introduced species growing under local conditions ;

(*b*) grassland management, both of natural grassland and of sown indigenous and introduced species, needs extensive investigation, and under this heading the effects on grassland of grazing animals, burning, manuring and cutting will need careful examination ;

(*c*) the question of restoration of fertility by grassland fallows (alternate husbandry) ;

(*d*) the soil and water conservation value of grassland ;

(*e*) the influence of grass rotations on the soil ;

(*f*) the question of finding suitable mixtures for putting down on land which is to be used for grazing ;

(*g*) finding suitable legumes for use in grass-legume mixtures ;

(*h*) an examination of the possibilities of producing fodder under irrigation ;

(*i*) hay and silage production.

Among others, the species which are being examined with regard to the points mentioned above, are :—

Pennisetum purpureum	Elephant grass (various strains)
Saccharum officinale	Sugarcane (ten different varieties)
Andropogon tectorum	Gamba (Southern Nigeria)
A. gayanus	Gamba (Northern Nigeria)
Panicum maximum	Guinea grass
Pennisetum clandestinum	Kikuyu grass (strains from Kenya and southern Nigeria)
Panicum repens	
Paspalum conjugatum	Sour grass, Green grass
Pennisetum spp.	both annuals and perennials (indigenous)
Pennisetum cenchroides	from South Africa
Cenchrus ciliaris	from South Africa
Panicum spp.	from South Africa, known there as Makarikari
Cynodon plectostachyum	Giant Star grass.

The main work with these so far has been :—

(*a*) testing drought resistance,
(*b*) reaction to cutting,
(*c*) reaction to manuring,
(*d*) reaction to grazing,
(*e*) testing methods of propagation.

Small scale experiments of the following kinds are in progress on the natural grassland of the middle belt :—

(*a*) testing the effect on botanical composition of burning in different seasons of the year, and at different intervals ;
(*b*) manuring of natural " pasture " grassland and its effect on botanical composition ;
(*c*) testing the effect on botanical composition of keeping natural " pasture " grassland cut short as against allowing it to grow away ;
(*d*) investigation of methods of establishment of some of the more useful local species such as *Andropogon gayanus, Pennisetum pedicellatum, P. subangustum* and other *Pennisetum* species.

The general programme of work for the future will be as indicated above. Ideally, of course, if the necessary facilities could be provided, one would wish to proceed along the lines suggested by Dr. Pole Evans, and deal with the problems in a big way, namely :—

(*a*) make a detailed pasture survey of the country,
(*b*) demarcate the different types of pasturage,
(*c*) work out the correct system of management for each,
(*d*) determine the carrying capacity of each under such management,
(*e*) work out a farming system best adapted to each kind of pasturage,
(*f*) to provide generally the basis for a new and constructive system of pastoral agriculture.

ANGLO-EGYPTIAN SUDAN: GRASSLAND REGIONS AND FORAGE PRODUCTION

The Anglo-Egyptian Sudan stretches from Wadi Halfa in the North (lat. 22°N) southwards over 18 degrees of latitude. In the Northern Province, north of Khartoum, (lat. 15°.36″N), rainfall is always insufficient to grow a crop, and cultivation is confined to the banks of the Nile, where irrigation from the river can be arranged, either by means of mechanically driven lift pumps or Persian wheels, ' shadoofs ' and other primitive appliances. In certain areas, when the Nile flood is sufficiently high, a number of ' basins '—low lying lands adjacent to the river—can be flooded at the peak of the flood by artificially constructed ' cuts ' through the Nile banks. This does not occur every year.

In Kassala Province, cultivation on " flood irrigation " can be done in the deltas of the Gash and Baraka rivers, which come down in flood during July to September; training works enable the Gash flood to be controlled and directed on to the land, but little can be done to guide the spread over the land of the Baraka water. These two deltas have cotton as their main crop, and millet (*Sorghum* sp.) as their secondary crop. Rain crops are grown in the Gedaref district in the South of the province.

In the rainfall areas south of Kosti (lat. 13°N. approx.) no rain falls between mid-November and mid-April; the amount which falls during the rest of the year is very variable, the 400 mm. isohyet runs just south of Kosti, turning N.E. to include Gedaref, and the Southern Sudan border coincides roughly with the 1500 mm. isohyet on the south-west and the 1200 mm. isohyet on the south-east. Between Khartoum and Kosti the rainfall is 100 to 400 mm. It is in this triangle, between the White Nile and the Blue Nile, that the irrigated concession area of the Sudan Plantations Syndicate lies. This " Gezira area " is, at this time, by far the most important agricultural area in the Sudan, in spite of its small size, both from the point of view of the value of the crops grown, and from its consequent revenue-producing capacity.

Thus, in considering the subject of this note, the Sudan falls into three natural areas :—

(*a*) the northern arid area,
(*b*) the Gezira,
(*c*) the Southern Sudan.

There is no need to sub-divide further from the pasture or forage crop aspect.

The Northern Arid Area

Rains here are light and natural grazing is frequently very scanty. Crops are grown by means of some form of irrigation and animals are fed on the haulms of pulse crops, the stalks of millet and maize, weeds culled from the growing crop or grown on the riverain stretches uncovered by the falling river. When the basins are flooded, the grass and weed growths on the uncropped areas are used for grazing. A particularly good fodder plant grows in the Kerma basin (opposite Dongala); this is a species of *Trigonella* (near *hamosa*) (Arabic name " kitieh "). Lucerne (*Medicago sativa*) was cultivated on a Government Pumping scheme at Gandeto (near Shendi)

until the mechanization of the 'Sudan Horse.' Otherwise it can be said that no single-purpose forage crop is grown. The most important fodder is the maize and millet stalks. The artificial propagation of kitieh in other parts of the country—particularly other basins in the Northern Province—might be worth investigation.

The Gezira

About 850,000 acres are irrigated by gravity water from the Sennar dam. A leguminous plant, *Dolichos lablab*, (Ar. lubia) is grown as a fodder crop in the rotation but does not play a very important part and is more often than not omitted. Practical considerations of cost of cultivation tend to keep the total area sown at a low level. The rainfall is greater in this area than further north, and weeds grow freely on the uncropped areas, which amount to more than 50 per cent of the irrigated land available. These weeds are grazed. The main forage is again the stalks of the large millet (*Sorghum*).

The growth of lubia has some beneficial effect on the soil, but its growth to the full extent permitted by the rotation will depend on the development of a more thrifty habit of mind in the cultivator, when he learns to stack his lubia against the days of scarcity in May and June, thus saving his animals from death by starvation.

Innumerable leguminous crops have been tried from all parts of the world, with a view to producing a better forage crop in the rotation than the local *Dolichos*, but no satisfactory substitute has yet been found. (These types include *Phaseolus* spp., soybeans, *Cajanus indicus*, *Mucuna* types, *Vigna* spp., *Melilotus*, *Cicer arietinum*, *Canavalia*, Hubam clover, "Teegapesalu," Velvet bean, etc. The most promising is probably a *Vigna* sp. known as Brabham's Cowpea).

The Southern Sudan

It is in the vast areas included in this heading that one might expect to see a trend in the type of native agriculture from the more primitive to the less primitive. There are, in fact, signs that development is proceeding, but it has not yet gone very far or fast. In Darfur Province, for example, in the Western Sudan, and in the Northern parts of Kordofan, the main interest is largely pastoral. The area is great and the population largely nomad. Sedentary cultivators are looked down on by the nomads. No real agricultural development has yet taken place in these areas—in fact, no agricultural officer has ever been stationed there.

In Southern Kordofan, which includes the Nuba Mountains, a cotton industry has developed during the last fifteen years, and more is known about the indigenous systems of agriculture there than elsewhere.

In the more thickly populated districts (Nubas), the available land is limited in extent and cropping is almost 'continuous.' A leguminous crop—frequently a *Vigna*—is here and there intercropped with the wide-spaced millet, helping to counteract soil exhaustion. *Sesamum indicum* may be intercropped with the millet instead of a legume; this is, in effect, similar to an ordinary rotation of crops.

In the non-Nuba area there is normally sufficient land to enable a shifting cultivation system to be used. When a patch of land has become exhausted, it is allowed to revert to grass, and new land is cleared, or land which has been growing grass is burnt and brought again into cultivation. This latter is known as "harig" (fire) cultivation and has an important place in the system. It is economical, but can be practised only on cotton soil plains, where a thick grass mat can be produced.

Experimental work has been started on certain aspects of this " grass period " in the rotation but so far no positive results have been reported. The best length of the resting period, following different periods of continuous cropping, and the possibility of reducing the resting period by hastening the establishment of these " harig " grasses more quickly by artificial means are aspects under consideration.

The most suitable harig grasses were found to be *Hyparrhenia pseudocymbaria*, *H. rufa* and *Brachiaria obtusiflora*.

In the Upper Nile Province, near Paloich, a practice has been reported among the Dinka tribe which is of interest. In the rains of one year the grasses are cut and left on the ground. The next year the large millet is sown, and again on the same land in 2 or 3 succeeding years. The land is then left for 3 or 4 years. The grasses regenerate in a definite succession and the cultivators judge that the land is ready for millet again when a particular grass reappears.

In Equatoria Province, continuous cropping for a time is again the rule, followed by a resting period when the land reverts to bush. It has been strongly recommended that this should become the regular practice. No experimental work is being undertaken now, but the work in Uganda on the use of Elephant grass (*Pennisetum purpureum*) as a rejuvenator of the land will be watched with interest as conditions there are somewhat similar.

Summary

The agricultural areas in the Sudan are largely undeveloped, with the exception of certain irrigated areas. Nowhere in the Sudan do grasslands form part of a rotation, though a start is being made in the introduction of some clear-cut system into the shifting cultivations of the rainfall areas, by allowing the natural regeneration of grasses on continuously cropped land to provide a resting period and a protection from erosion. The regeneration may be hastened artificially. It seems unlikely that any large step forward in the use of forage crops and grass swards as an integral part of the native agricultural system will take place until there is a much greater pressure on the available land.

ZANZIBAR: GRASSLAND TYPES AND FORAGE PRODUCTION

Descriptive

The dominant type of vegetation in the Protectorate is not grassland, the feature of the landscape being the growth of woody plants, either shrubs or trees. Where a grass cover occurs, it persists either because repeated fires sweep through the open bush, destroying and eating further into the woody growth, or because of constant grazing by cattle in the vicinity of villages and squatters' huts. An exception to this is the limited grassland area which occurs on Zanzibar Island as flat plains, but these situations are poorly drained and remain wet for most of the year.

The soils of both islands consist of two main types: a moderately fertile and deep soil which is given over almost entirely to the growth of clove and coconut trees, and a much poorer area consisting of an outcrop of coral limestone rock. Whereas in Zanzibar the better soil type occurs only on the western side, covering not more than half the total area of the island, in Pemba good soils are more extensive and the eastern area of poor soils less wide than in Zanzibar.

The poorer limestone area may be further divided into a more or less open bush type of country where the rock outcrops frequently through a thin soil cover, and an impenetrable closed bush formation growing in the holes and crevices of the jagged coral rock which forms a part of the coastal fringe.

The clove and coconut area is the more important agriculturally and contains the bulk of the population.

The open bush zone which is so extensive in Zanzibar but not in Pemba is unimportant either from an agricultural or pastoral point of view since it is sparsely inhabited and badly watered.

Within the closed bush formation are many of the small fishing villages whose inhabitants are also agriculturists and they can only with much difficulty win a meagre harvest of crops from the pockets of earth and humus in the rock. In this area, the chief agricultural implement is a crowbar.

In the important clove and coconut area, most of the land is owned by Arabs and many of the plantations are large. The labourers on the plantations are squatters composed of a mixed population of local and other Africans. The remainder of the land is either held by Government for the use of the local inhabitants, or communally-owned or, in some parts, privately owned.

Climate

The climate of Zanzibar and Pemba is similar to that of the low-lying coastal belt on the East African mainland. The chief features are fairly high temperature with small range, both diurnal and annual, consistently high humidity and maximum rainfall about April and May. The climate is governed largely by the monsoons. The south-west monsoon brings in the heavy rains and cool season. The short rains, which are very variable from year to year, occur about the end of November and beginning of December at the onset of the north-east monsoon. The hottest months are November and March and the driest months December, January and February.

Records of average annual rainfall in different localities on Zanzibar island range between 47.6 and 75.9 inches, and in Pemba island between 65.7 and 93.5 inches.

The average temperature at Zanzibar for the year is 79.5°F., and the diurnal variation has a range of 8°F.

Population

The mixed population may be broadly classified as Arabs, Africans, and Non-Africans, but the Arabs and Africans have intermixed to some extent, and the Africans would also include local Africans and other Africans. The total population amounts to nearly two hundred and fifty thousand people, of whom the Arabs number some thirty to thirty-five thousand and the Africans nearly two hundred thousand. As has been mentioned above, the bulk of the population is centred in the clove and coconut growing areas. Approximately forty thousand people reside in the town of Zanzibar itself.

Although the combined Arab and African population in the Districts of the two islands is nearly similar at between ninety and ninety-five thousand, the distribution is much more favourable in Pemba than in Zanzibar : there is no big consuming town population in Pemba as there is in Zanzibar.

Livestock

The latest cattle census figures are :—

Island	*Area in sq. miles*	*Number of Cattle*
Zanzibar	640	6,908
Pemba	380	23,153

There is no satisfactory explanation to account for the difference in the density of the cattle population in the two islands. Outside the neighbourhood of the town of Zanzibar, the type of animal is the Zebu, and almost all are owned by the Africans, either by squatters or labourers on the plantations or those farming for themselves. These cattle are tethered for their grazing. Of the total of about seven thousand head of cattle on Zanzibar island, some four thousand are within a radius of 5 miles of Zanzibar Town and are practically all owned by Indian dairymen engaged in supplying fresh milk to the town. These dairy herds are composed for the most part of half and three-quarter grade cows. The crosses show that various types of European breeds, chiefly Friesian and Ayrshire, have been used. They are grazed in herds and are given supplementary feeding.

The consumption of meat outside the townships is inconsiderable and very little of the requirement of meat of the more wealthy residents of the townships is provided by the slaughter of local cattle. Some two thousand head of cattle and six thousand head of sheep and goats are imported annually from the mainland for slaughter. Surplus milk from the country finds a ready sale in the townships and other small centres.

Pending a thorough veterinary survey of the whole Protectorate, which is envisaged in the near future, no accurate information is available regarding either the cattle population or the disease position. It is thought that the cattle population has remained fairly constant. East Coast Fever is regarded as being solidly enzootic. There has been a heavy infection of trypanosomiasis in the past in Zanzibar, and it has always been considered that this infection was maintained by mechanical transmission by biting flies other than *Glossina*. Since 1927 the Protectorate has been free of rinderpest. Cases of contagious bovine pleuro-pneumonia have occurred,

but none have been detected in recent years. Anthrax occurs sporadically. Little or nothing is known of the incidence of other diseases.

Management of Grazing and Fodder Crops

Until very recently all investigational work has been mainly concentrated on the two plantation crops of cloves and copra. The activities of the veterinary branch had been connected only with such duties as supervision of dairies, meat inspection and preventive quarantine control measures in relation to imported livestock. More recently these activities have been expanded to investigate the cattle position in the field, but no progress can be expected until the proposed stock survey is conducted and the problem of disease tackled. The foundations for the improvement and development of the livestock industry have recently been laid by the establishment of a stock farm at the Kizimbani Station where a breeding herd of selected local cattle is being built up and where investigations have also been commenced on the question of pasture management and the cultivation of fodder crops. It will be seen, therefore, that the present position is that we have no accurate information to give on the problems of pastures and fodder crops. So far, we have ascertained that the stock-carrying capacity of the unimproved grazing available in the clove-growing areas is only about 3 acres per beast. We know that only by careful management and attention to the prevention of the encroachment of weeds and non-herbaceous growth can a satisfactory cover of a moderately nutritive perennial grass (*Panicum trichocladum*) be established in paddocks. At present this is the most important fodder grass in Zanzibar and Pemba and is common everywhere except on the coral limestone. It is cut and carried into Zanzibar and sold for fodder and also cut and fed to stock in the districts. Its habit is trailing and it is not very leafy, but when established and grazed as a pasture it may be expected to grow more densely.

Trials have been commenced with fodder grasses. Indigenous Guinea grass (*Panicum maximum*) and indigenous elephant grass (*Pennisetum purpureum*) are under cultivation. Kudzu vine (*Pueraria thunbergiana*) flourishes and seeds profusely and is being further investigated. A few years ago it was established in an area under coconuts where, as a result of repeated hard grazing, it formed a mixed cover with other grasses including spear grass (*Imperata cylindrica*). From observations there would, therefore, appear to be some prospect of establishing Kudzu vine as an ingredient in a better herbage association under certain conditions. In the management of these pastures and cultivated fodders, the question of manuring with locally produced manures is being investigated. Extensions of these trials with other species in areas outside the above belt are under consideration.

In the well-populated clove-growing area, there is the peculiar position of the land belonging to the Arab plantation owner and the cattle living within it belonging to squatters and labourers who never own more than one or two animals each. These animals are always tethered and receive a considerable amount of personal attention and care from their owners. Generally speaking, the bite available is a very mixed one and includes *Panicum trichocladum*, *Imperata cylindrica*, *Digitaria* sp., *Sorghum verticilliflorum*, *Rottboellia exaltata*, and a creeping *Desmodium*, all depending upon the state of the canopy overhead, the situation, and the management of the plantation. Weed growth is usually prolific. In Zanzibar the numbers of stock kept in this area are never high and there is always sufficient forage available throughout the

year, the only necessity being for the owner to move his tethered animal often enough. In Pemba where the stock population is higher, the area under cloves far greater, and the development of the clove tree on the whole better, there is less forage for cattle in the plantations and consequently there is great competition in the numerous small valleys between the needs of the people for cultivating rice and other crops, and grazing for the stock. Even after the rice crop has been taken off the pressure by stock for grazing is considerable and the quality of the herbage available is often very poor.

It may be observed at this point that the wartime need to produce the maximum quantity of foodstuffs locally has radically altered the normal balance. There has been so much land cultivated to root crops and rice that stockowners, especially in Pemba but even in Zanzibar, find great difficulty in obtaining the necessary grazing, and in some parts they have preferred, unwillingly in the face of necessity, to dispose of stock.

In the more or less open bush areas which consist of an association of *Anona* sp., *Vitex* and *Eugenia* sp., the chief grasses are *Hyparrhenia rufa* and *Digitaria milanjiana*. Closer to the east coast where the soil cover is no more than a skin on the coral limestone and the dry conditions more pronounced, the dominant grass is *Heteropogon contortus* with patches of *Dactyloctenium aegypticum*. On the fringing closed bush formation of the *Euclea—Mimusops* association, there is no grass cover.

The open bush areas are scarcely grazed at all except where they adjoin either the clover areas or the closed bush formation near the fishing villages. Despite the far more severe conditions of dryness, the stock grazing on the *Heteropogon* and *Dactyloctenium* areas keep in remarkably good sleek condition. These grazing grounds are fired seasonally to bring on a green flush before the arrival of the rains. In an exceptionally severe season, Baobab leaves are cut and fed green.

In conclusion, it may be said that the immediate necessity for the betterment of the livestock industry is to be able to control those diseases of which the incidence is very little known. There is no doubt that the cattle industry on Zanzibar Island is not in a flourishing condition and no reason can be given to explain it. The next step is the provision in numbers of a better quality of the local animal which can only be arrived at by years of selective breeding. It seems unlikely from what has been said in the earlier paragraphs that until a more profitable animal can be owned the owner will trouble himself to improve what are already fairly good conditions for his stock either by the purchase of cheap food to supplement the grazing or even to spend his labour improving the grazing himself and cultivating fodder crops. The cattle here are owned in twos and threes by individual families and are well looked after. The bulls and donkeys used by transporters are remarkably well cared for and are given very adequate feeding which includes purchased rations, normally very cheap, because the owner is well alive to the value of keeping his animal in first-class working conditions. Peasant owners of cows in the vicinity of the professional Indian dairymen, and who themselves make a sideline of selling milk to town, realize the benefit of mating their poor native cows with grade bulls. Given better material there can be little doubt that the care of it will be proportionately increased since it will be appreciated what standard of feeding is required in producing more milk. The provision of the better material and the investigation into the feeding requirements including pasture management and fodder crops are being undertaken at the Department's Experiment Station. Model holdings to demonstrate mixed farming are also being established.

SOUTHERN RHODESIA: GRASSLAND MANAGEMENT AND RESEARCH

Economic Aspects of Established Pastures

The acreage of established pastures in Southern Rhodesia has shown little increase during the last few years. Farmers, however, continue to experiment with these pastures, though with varying success. In an attempt to determine their value more precisely on the sandveld areas of this Colony, experiments were started at the Grasslands Station, Marandellas, in 1939 by the Pasture Research Committee of the Department of Agriculture and Lands.

The Grasslands Station is situated 3 miles west of Marandellas at approximately 5,200 feet above sea level. The vegetation is a typical Msasa (*Brachystegia*) grassland association with fairly heavily wooded areas drained by open vlei land. The soils are mostly poor granite sands, except for a small area of semi-compact soil. The farm is considered to be typical of a large area of poorer granite highveld. It is an area more suitable for stock farming than for agriculture, and established pastures to supplement the grazing and lessen the dependence on agriculture for stock feed would be of great value if they could be shown to be an economic proposition.

Grazing Experiments

Plan of the Experiments. The general scheme of the experiments is to compare the productivity of the natural veld with various established grasses. Comparable groups of dairy and beef cattle are maintained on the pastures under investigation and the production of these cattle, either in milk or beef, is compared. At the same time, grazing records and control areas are kept whereby the effect of the various systems of management and rates of stocking on the vegetation can eventually be compared when facilities are available.

The chief cultivated grasses used in the experiments are paspalum (*Paspalum dilatatum* and *P. virgatum*) on the vlei soils and Rhodes grass (*Chloris gayana*) on the upland soils. Some Rhodes grass seed was mixed with the paspalum to give a quick cover and as a precaution against erosion. This Rhodes grass has persisted only in the drier areas of the vlei. As good a seed bed as practicable was prepared for all cultivated pastures and approximately 30 acres of vlei pasture and 80 acres of Rhodes grass have been laid down and utilized so far in these experiments. The vlei pastures receive dressings of artificial fertilizers, usually 100–200 lb. of ammonium sulphate per acre per annum, and are limed at the rate of 1 ton per acre before seeding.

The natural veld to be compared with these pastures has been sub-divided into numerous camps of suitable sizes, all provided with good water and adequate shade. Surplus vegetation is either mown and made into hay or burned off, according to the treatment required in the particular experiment.

The beef cattle used in these experiments have been purchased as weaners from ranches in Matabeleland, usually at an age of 12 to 15 months. They are despatched to the Rhodes Matopo Estate, Bulawayo, as stores when about 3½ years of age for fattening. The dairy cows are Freisland grades imported as heifers from good grade herds in the Union of South Africa early in 1939.

Experiments with Beef Cattle. Two trials have been carried out; No. 1 has been completed, No. 2 is nearing completion. Three groups in Trial 1 and 4 groups in Trial 2 are comparable and only the data from these groups are summarized here,

The groups are :—

Group 1 : Free range on natural veld, fenced, and allowing approximately 15 acres per head. No supplementary feed or hay.

Group 2 : Similar grazing and treatment to Group 1, but the cattle receive a protein concentrate in the winter months.

Group 3 : Rotational grazing on natural veld that has been paddocked, cleared and stumped of trees except for a few shade trees ; 7 to 8 acres are allowed per head. Veld hay cut in these paddocks is fed in the winter months.

Group 4 : Established pastures consisting of paspalum in the dry season and Rhodes grass in the summer ; approximately 3 acres are allowed per head. Surplus Rhodes grass hay from these paddocks is fed as required in the winter.

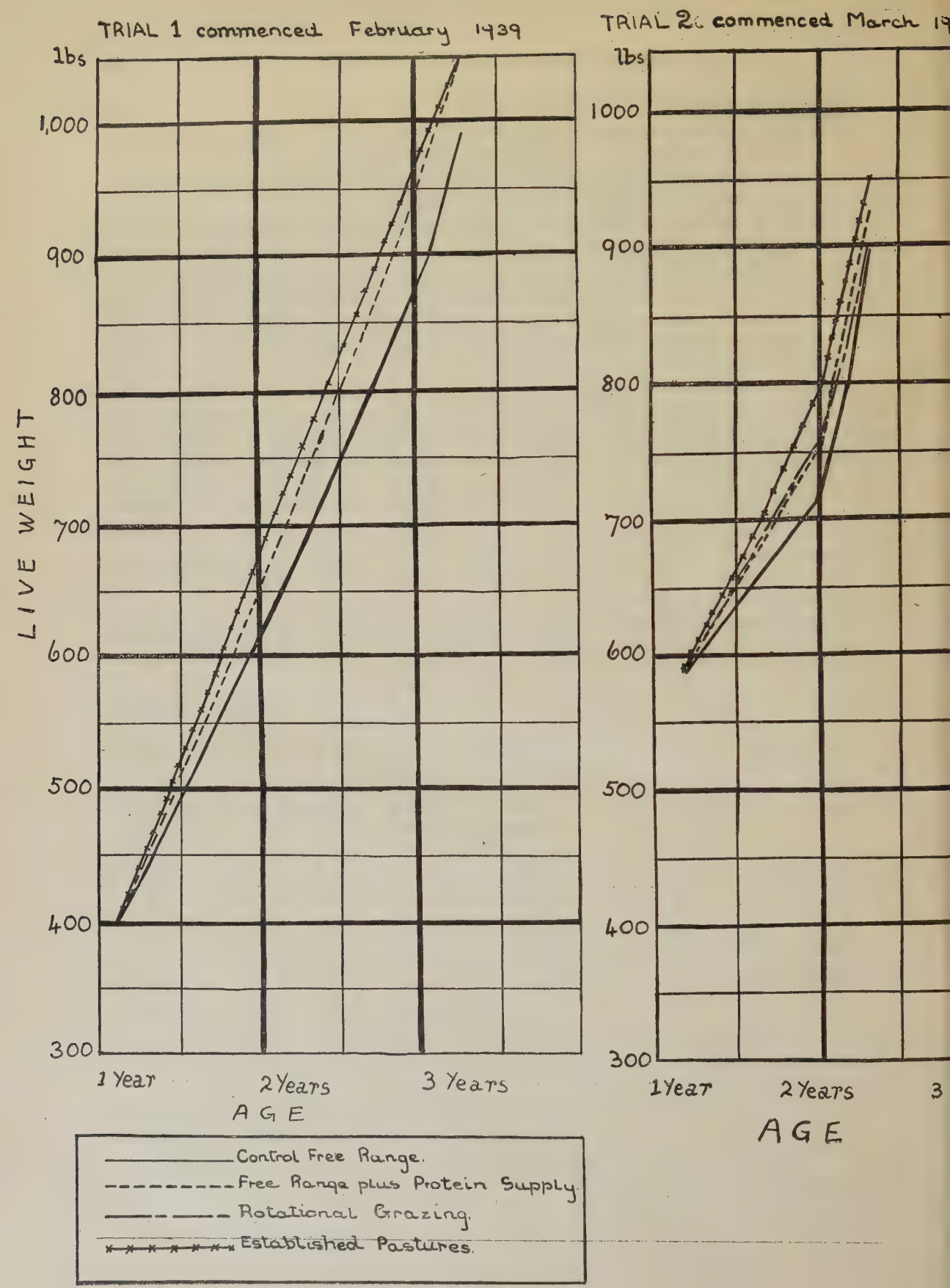
The areas utilized per head have been decided arbitrarily and represent the extent considered necessary under the system followed to maintain good growth in cattle under local conditions. It has not been thought necessary to modify these estimates in the 5 years during which the experiments have been in progress. The actual areas utilized are not considered important as the grazing varies from camp to camp. What is of more importance are the results achieved under the different systems of management, i.e. free range or rotational grazing on natural veld and established pastures. The cattle are changed from camp to camp according to the state of the grazing. The protein concentrate in most winters has been 1 to 1.5 lb. of whole cottonseed per head per day.

All cattle are dipped regularly and receive salt as the only mineral supplement.

The results are presented in Fig. 1 and further data are given in Table 1.

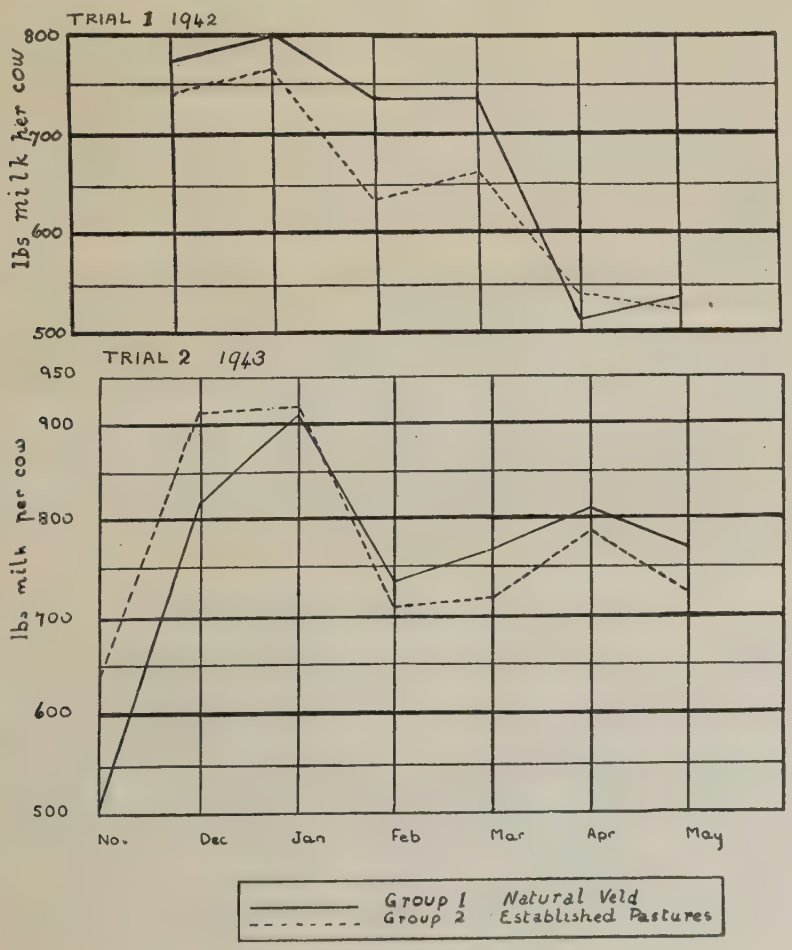
TABLE I. BEEF CATTLE : GAIN IN LIVEWEIGHT

	Groups			
	1	2	3	4
	Free Range lb.	Free Range + Proteins lb.	Rotational grazing lb.	Established pastures lb.
	Trial 1—10 steers.			
February, 1939	396	396		396
January, 1940	613	647		678
January, 1941	865	941		969
May, 1941	996	1049		1053
	Trial 2—12 steers			
March, 1942	588	588	586	587
January, 1943	715	755	759	789
May, 1943	895	932	902	958


TRIAL 1 commenced February 1939
TRIAL 2 commenced March 19
lbs
1,000
900
800
700
600
500
400
300
LIVE WEIGHT
1 Year
2 Years
3 Years
AGE
Control Free Range.
Free Range plus Protein Supply.
Rotational Grazing.
Established Pastures.

All groups have done well as judged by local standards and the difference in the store weights of the different lots is not considered significant. In Trial 1 the average cold dressed weight of the steers in Groups 1, 2 and 4 were 652, 705, and 758 lb. respectively. There was no difference in the grading of the carcases of the three groups after slaughter.

The area used in the case of the established pastures is very much less than with the natural veld, but where land is cheap this saving in area has not been sufficient under the conditions of this experiment to justify the extra cost of establishing and maintaining these cultivated pastures. In all four winters the cultivated pastures have produced sufficient feed to prevent any excessive loss of weight in the cattle grazing on them. By removing the fairly thick tree growth the carrying capacity of the natural veld has also been greatly increased. The extent to which such clearing is an economic proposition depends on the price of land and cattle and the amount of clearing which has to be done to effect the improvement required. The economic aspects of this problem would have to be considered separately for each case. The chief value of the results, however, has been to demonstrate the excellent results which can be obtained from natural veld grazing.



Experiment with Dairy Cattle. Two trials have been completed. Trial 1 in 1942, in which year the rainfall was much below normal, had to be discontinued in May owing to shortage of grazing on the veld. Trial 2 in 1943, a season of good rainfall, was still in progress in July. It should be stressed here that the success of these vlei pastures is governed by the amount of moisture in the soil during the winter months. If irrigation is not available in an unfavourable season they dry up in the same way as the natural veld and the improved grasses on them yield little feed.

In each trial one group of cows was grazed on established pastures, in the same way as the steers, at the rate of 3 acres per cow, while the control group was allowed unrestricted veld grazing. Supplementary concentrates were fed to both groups at the same level, i.e. 2 to 3 lb. of concentrates per gallon, depending on the maturity of the grazing, though in the earlier stages of Trial 1, the group on established pastures received less concentrates than the control group. Towards the end of the summer, April or May, the control group receives a supplementary ration of hay and silage in addition to the grain, while the other group remains on the established pastures until it is evident that these pastures are producing less feed than will maintain cows in milk and when receiving a normal grain ration. The general scale of feeding for the control group is based on the usual farm practice in this area for cream production.

The effect of supplementary feeding, both with beef and dairy cattle, has varied with the season and with the palatability and stage of maturity of the grass available. Supplementary feeding is fraught with complications in practice, as the use of such feed influences the grazing habits of the animals and the use they make of the pasture. The scale of feeding from time to time has therefore been planned to induce the animals to consume, as far as reasonable, the maximum quantity of grass for the type of stock concerned.

In both trials the milk production of the two groups has been the same and the small changes in liveweight were the same for both groups. The established pastures led to a saving per cow of approximately 200 lb. legume hay and 600 lb. of maize silage in Trial 1 up to the end of May, and of 1 ton of legume hay and a little more than half a ton of silage in Trial 2 up to the end of July. The cost of establishing these cultivated pastures has varied at Marandellas from £2 to £3 per acre, while the cost of fertilizing with ammonium sulphate at £10 per ton has varied from 10s. to 20s. per acre per annum. As 3 acres per cow have been utilized, this saving in feed has hardly justified the extra expenditure.

Artificial Fertilizers and Compost

From an economic standpoint the results noted in the above section are disappointing, but work has also been in progress to determine how better returns might be obtained either from the natural veld or from other cultivated grasses or crops. The fundamental cause of the low returns appears to be the low fertility of the soils on the Station, which makes it difficult to establish high-yielding grasses or to apply economically intensive methods of utilization of grass. Work has therefore been carried out to increase productivity of pastures by :—

(*a*) the use of artificial fertilizers and compost, and
(*b*) the introduction of other grasses.

TABLE 2. DAIRY CATTLE: MONTHLY MILK PRODUCTION PER COW

	GROUP 1 Natural veld. lb.	GROUP 2 Established Pastures. lb.
	Trial 1 : 7 cows per group.	
1941		
November	—	—
December	774	741
1942		
January	805	763
February	736	641
March	736	657
April	513	545
May	535	530
	Trial 2 : 9 cows per group.	
November	509	632
December	822	911
1943		
January	907	922
February	747	712
March	771	726
April	808	790
May	772	719
June	629	646
July	555	535

Many data on the effect of artificial fertilizers on the natural veld in this area have been accumulated by the Chief Chemist, whose original experiments were laid down in 1929, when an area of approximately 500 acres was divided into 20 acre paddocks and cleared of all bush except a small number of large trees, which were left to give shade to the grazing animals in these experiments.

The paddocks were divided into five groups and were fertilized as follows :—

Group 1.—200 lb. rock phosphate per acre (34 per cent P_2O_5).
Group 2.—200 lb. superphosphate per acre (19 per cent P_2O_5).
Group 3.—200 lb. superphosphate + 100 lb. muriate of potash per acre.
Group 4.—200 lb. superphosphate + 100 lb. muriate of potash + 100 lb. ammonium sulphate per acre.
Group 5.—Control.

These treatments were applied to the various groups of paddocks for three successive years. Each year the hay from the various paddocks was cut and composite samples of hay from each paddock were analysed. Analyses were also made at different stages of maturity to follow the changes in composition as the grass matured.

The results of the fertilizer treatment as shown in Table 3 are extremely disappointing.

TABLE 3. YIELDS OF HAY IN LB. PER ACRE

Treatment	1931	1932	1933	1934	1935	Average for first 5 years 1931-35.
N.P.K.	1,185	1,631	1,521	1,225	948	1,302
P.K.	875	1,310	941	1,009	823	992
Superphosphate	871	1,034	905	1,035	667	902
Raw Rock	627	960	682	844	658	794
Control	890	951	621	703	523	738

Treatment	1936	1937	1938	1939	Average last 4 years 1936-39
N.P.K.	1,396	822	1,191	1,355	1,191
P.K.	1,297	761	833	1,126	1,004
Superphosphate	1,275	591	1,034	1,178	1,020
Raw Rock	762	429	692	775	665
Control	1,316*	641*	826	1,152	984

*100 lb. per acre sulphate of ammonia.

Complete fertilizer shows the greatest increase in yield over the control. The increase, however, is negligible in relation to the cost of the fertilizer, and indicates that the application of artificial fertilizers is not likely to play a great part in the improvement of natural veld of this type under present conditions. The results show that the influence of fertilization is more marked on the quantity than the quality factor, although the hay from the fertilized paddocks was slightly superior in feeding value. The important seasonal effect of rainfall is shown in Table 4.

Cultivated grasses have shown a greater response to fertilizers than the natural veld. For instance, the longevity trials with Rhodes grass at this Station have shown definitely that this grass responds to fertilizer; by applying a dressing of 6 tons of compost plus 200 lb. of complete grass fertilizer (P_2O_5 = 14.5 per cent, N = 10 per cent, K_2O = 3 per cent) per acre every second year, it is possible to maintain a yield of 1.5 tons per acre over a 5 year period, while the control plot and plots fertilized annually with 100 lb. of ammonium sulphate per acre have decreased in yield over the same period from 2 tons to 0.5 ton of hay per acre.

Similarly, plots of paspalum pasture established with heavy dressings of compost 10 to 20 tons) and 500 lb. of superphosphate per acre in the growing season of 1941

TABLE 4. YIELDS OF HAY, IN LB. PER ACRE, COMPARING SEVEN SEASONS OF GOOD YIELDS WITH TWO SEASONS OF POOR YIELDS

Treatment	Average yield for 9 years 1931-1939	Average 7 good years.	Average 2 poor years 1935-1937
N.P.K.	1,253	1,357	885
P.K.	998	1,056	792
Superphosphate	954	1,047	629
Raw Rock	736	763	544
Control	847	923	582

showed a much more vigorous stand of grass in 1943 than paspalum pasture established in 1940 without such fertilizing.

The dressings necessary to obtain these stands do not appear economic at the present stage of agricultural development in this Colony and attention has, therefore, been directed at the same time to the trial of other grasses which do not require so much feeding.

THE INTRODUCTION OF OTHER GRASSES

Two grass gardens have been established at this Station, one by the Chief Agriculturist in 1930 on vlei soil, and the other in 1938–39 on upland soil by the Pasture Research Committee.

In each case, a large number of African grasses were tried which were thought to show signs of promise under local conditions. These plots were kept clear of weeds and other grass for a period of 2 years to give the grasses a reasonable chance to become established.

In the first series of trials, only three grasses survived and managed to maintain themselves against the competition of the indigenous grass. These were :—

Swamp couch (*Hemarthria fasciculata* Kunth).
Swamp ryegrass (*Acrocerus macrum* Stapf).
Creeping false paspalum (*Brachiaria dictyoneura* Stapf).

The two former have proved vigorous and able to maintain themselves in a comparatively pure stand for at least 5 years. Swamp couch has not proved very palatable to cattle on this Station unless it is closely grazed, which is not easy to do in the wet season. Creeping false paspalum is well liked by stock but does not appear to produce much bulk of feed on this Station. On the diorite soil at the Salisbury Experiment Station this grass has provided 231 grazing days per acre per annum over a 7-year period. All three grasses have been able to persist under conditions where paspalum has been overcome by the indigenous grasses and are worth further extended trial for vlei, or semi-vlei, pastures.

In the second series of experiments three grasses again proved far superior to the others tried. These are :—

Naivasha star grass (*Cynodon plectostachyum* Pilger).
Crowsfoot grass (*Dactyloctenium aegyptium* Richt.).
Purple topped buffel (*Panicum coloratum* Linn.).

Extended areas, totalling 20 acres of the two former grasses, have now been established without fertilizing and so far show distinct promises, making excellent calf and dairy cow pastures, although in the third year local couch grass (mainly *Cynodon dactylon* Pers.) is apparently beginning to subdue the star grass.

Further grasses have been planted out in 1942–43. Trials with clovers have also been carried out.

The Establishment of Tame Pastures

Owing to the necessity for irrigation and the high cost of establishment, very little attention has been paid by farmers to the laying down of winter-hardy pastures, and the results so far obtained have not been encouraging, owing to the competition of indigenous summer grasses and weeds. Attention, therefore, may be here confined to the establishment of summer grasses. Of these, the majority of the suitable varieties have to be established by vegetative propagation since their production of viable seed is very low; it is, therefore, clear that the use of short-term leys (1 to 3 years) of these grasses is not generally practicable, especially in view of the danger of serious erosion of the seed bed by the heavy rainstorms, which may amount to several inches of rain in about half an hour.

Of the grasses of which seed is commercially obtainable, only two have so far proved at all suitable, namely, Rhodes grass (*Chloris gayana*) and *Paspalum dilatatum*, but they have a limited range of usefulness. Of these, the former will cover the soil comparatively rapidly and protect it from serious erosion, but the latter normally requires one and a half to two years in which to produce a cover which is effective against erosion. For this reason, the sowing of a few pounds of Rhodes grass seed with paspalum is advocated, in order to prevent the loss of the top soil whilst the latter is establishing a cover.

Besides the danger of serious erosion of the seed bed, the periodical droughts which inevitably occur during the planting season (November to February), and which may last for several weeks, are a further constant threat to successful establishment of pastures, particularly where they are sown. However, the more serious danger comes from the threat of erosion of the seed bed, since in extreme cases the whole of the top soil may be lost during the single heavy rainstorm. Special precautions to prevent this are, therefore, very necessary, where any considerable area is to be grassed. The whole area should be protected by the construction of suitable storm-water drains, and contour ridges.

Where grasses are to be propagated vegetatively from root divisions, runners, etc., it is recommended that the soil should have as rough a tilth as practicable. After the grass has taken root, if it is a variety which spreads by surface runners, a finer tilth is necessary to enable the runners to root down easily; this may be obtained by a stroke or two of a light spike harrow, just before the runners are developed.

Where grasses are to be sown and a very fine seed bed is necessary, the sowing of sunn hemp (*Crotalaria juncea*) as a nurse crop with the grasses is advocated, in order to protect this from local erosion (between contour ridges). This should be broadcast and covered before the sowing of the grasses, since it requires to be covered more deeply than the latter. A light seeding of 10 to 15 lb. per acre is suitable. The sunn

hemp grows very rapidly and soon serves to hold the fine seed bed in place. It also serves to break a surface crust if this forms on the soil after rain, and thus helps the delicate grass seedlings to emerge. After it has served its purpose, the sunn hemp can be utilized as hay, or for conversion into compost, in cattle kraals or pens made on the headlands of the field, or simply left to mature seed. The sunn hemp nurse crop is also very effective in controlling weeds, and the root system enriches the soil in humus.

Where tame pastures are being laid down on hilly country on virgin grassland, a simple and effective means of controlling soil erosion is by the employment of " contour-strip " sowing. In this system, alternate strips of virgin grass are left between the strips sown to tame grass in the first season, and in the second season the virgin strips are ploughed and sown. The strips run with the contours of the ground, and the steeper the slope the narrower is the width of the alternate strips of virgin grass and tame grasses. On the steeper slopes the strips may be as narrow as 10 yards, and on lesser slopes as wide as 20 to 30 yards. The strips of virgin grass serve to check erosion in the first season, and sunn hemp may with advantage be seeded with the tame grasses as described above in order further to control erosion.

The best seed bed on which to sow grasses is obtained if a heavy seeding of sunn hemp (40 lb. per acre) precedes the sowing of the grasses. The sunn hemp may be reaped for hay or seed, preferably the latter.

On the stubble, the all-important fine and very firm seed bed is easily and cheaply prepared by disc harrowing followed by spike harrowing. In addition weeds are reduced by the smothering action of the sunn hemp, and the decay of the root system in the soil yields a generous supply of nitrogen to give the young grass a good start in life, and leaves many channels to assist its roots to penetrate the soil easily.

In the establishment of grass by vegetative propagation, it may be mentioned that the normal method is by digging holes with the hoe, and planting therein the root divisions, or runners. In the case of Napier fodder (*Pennisetum purpureum*), sections of year-old stems are sometimes dropped in the furrow behind a two-furrow plough, and covered by the next stroke of the plough. The spacing of the root divisions will vary from 2 feet by 2 feet, or 36 by 18 inches for the tufted or less vigorous running grasses, up to a spacing of 3 feet by 3 feet for the more vigorous running grasses such as swamp couch (*Hemarthria fasciculata*), or Milanje grass (*Digitaria milanjiana*).

Conclusions Regarding Pasture Management

The work carried out so far has demonstrated the considerable potentialities of this type of sandveld. It has shown the excellent results which can be obtained from the natural grazing. In the experiments with cattle, described, however, the rate of growth of beef cattle or the milk production of dairy cows has not been much improved either by the intensive method of grazing management or by the use of cultivated pastures, although the area of grazing required per beast is much reduced.

The soils in this area are not sufficiently fertile to carry either paspalum or Rhodes grass under the methods adopted, except where these grasses are fertilized at a rate which at present appears uneconomic in the production of beef or butter fat. It must be appreciated, however, that with products of high value, such as whole milk or pedigree stock, these pastures would yield a greater return.

These results are disappointing, but they have been obtained on poor soils. Other experiments carried out by the Department, as well as practical experience, have shown that on more fertile soils or where moisture conditions are more even throughout the year, as on the Eastern Border or where irrigation is available, much more favourable results can be obtained from intensive methods of grazing or from cultivated pastures than have resulted at Marandellas. It is in these better areas that most development in pasture improvement may be looked for at present.

SOUTHERN RHODESIA: TRIALS WITH INDIGENOUS AND INTRODUCED GRASSES

Investigations into the merits of local species of grasses were commenced in the year 1919, when a number of indigenous grasses reputed to be favoured by farm livestock were collected and planted in separate beds. The collection was increased during the years which followed, by importations from neighbouring African States, other British Colonies, and foreign countries as well. All the best-known grasses of countries where climatic conditions are similar to Rhodesian conditions, and many of the grasses from countries where the climate is dissimilar, have been included in these trials.

The soil at the Agricultural Experiment Station, Salisbury, is reddish-brown dolerite loam, similar to that in the maize belt of this Colony. The grasses depend on the natural precipitation of rain, which averages about 32 inches per annum.

Within a few years it became apparent that only grasses of African origin were able to thrive under the soil and climatic conditions normally found at this Station. The following list contains the names of the more important grasses included in these trials. Those marked with an asterisk were imported from overseas.

Anthephora pubescens
Andropogon gayanus var. *squamulatus*
Amphilophis insculpta
Brachiaria brizantha
Brachiaria dictyoneura
Cynodon dactylon
Cynodon plectostachyum
Chloridion cameronii
Digitaria scalarum
Digitaria pentzii
Digitaria setivalva
Echinochloa pyramidalis
Hemarthria fasciculata
Ischaemum glaucostachyum
**Melinis minutiflora*
Panicum coloratum
**Paspalum dilatatum*
Paspalum scrobiculatum
**Pennisetum merkeri*
**Andropogon sericeus*
Acroceras macrum
Beckeropsis unisetum
Brachiaria mutica
Brachiaria nigropedata
**Bouteloua curtipendula*
Cynodon hirsutus
Cenchrus ciliaris
Chloris gayana
Digitaria gazensis
Digitaria milanjiana
Eustachys paspaloides
**Hyparrhenia rufa*
Leersia hexandra
Panicum maximum
**Phalaris tuberosa*
**Paspalum urvillei*
Paspalum notatum
Pennisetum purpureum
Pennisetum clandestinum

Rottboellia exaltata
Setaria splendida
Setaria sphacelata
Setaria pabularis
Setaria longiseta
Sorghum versicolor
Themeda triandra
Rhynchelytrum nyassanum
Urochloa pullulans
Setaria megaphylla
Setaria phragmitoides
Setaria lindenbergiana
Setaria plicatilis
Sorghum arundinaceum
Sporobolus pyramidalis
Rhynchelytrum roseum
Urochloa mosambicensis
Urochloa bulbodes

Although certain strains of both *Hyparrhenia rufa* and *Melinis minutiflora* are indigenous to this Colony, the strains used in these trials were imported from Brazil. They have a larger proportion of leafy growth than the local strains, but as their seed matures very late in the season, it is usually damaged by frost before it reaches maturity. For this reason they are not well suited to local conditions.

Acroceras macrum, Brachiaria mutica, Echinochloa pyramidalis, Hemarthria fasciculata, Leersia hexandra, Pennisetum clandestinum and *Paspalum* spp. have proved very suitable for low-lying land in other parts of this Colony, but the long periods of drought normally experienced between the seasonal rains cause them to weaken and eventually die out when they are used for pasture on the uplands, where they have to depend on the natural precipitation only.

Recent introductions from the Union of South Africa include the following species and strains :—

Digitaria decumbens ; *Digitaria pentzii* (Messina strain) ; *Digitaria pentzii* (Vryburg strain) ; *Digitaria* sp. Port Elizabeth strain ; *Digitaria* Malmaniesoog ; *Digitaria* Waterval ; *Digitaria valida* Koster strain ; *Digitaria valida* (Slurry strain) ; *Digitaria smutsii* ; *Digitaria swazilandensis* ; *Digitaria* Northern Rhodesia strain ; *Panicum* Makarikari ; a number of *Cynodon* species which originated in Kenya Colony have also been received, but as it was not possible to plant them in test plots until this season, their merits for local conditions cannot yet be estimated.

The genera *Digitaria, Panicum* and *Urochloa* provide the largest number of species suitable for the establishment of artificial pastures, but other genera, such as *Chloris, Brachiaria, Chloridion, Cynodon, Ischaemum, Setaria, Sorghum, Themeda* and *Rhynchelytrum* provide palatable species of considerable merit, which deserve the attention of investigators.

During the seasons 1929–32, small paddocks, each two-thirds of an acre in extent, were laid down to the following grasses :—

(1) *Digitaria pentzii,* Vryburg strain.
(2) *Chloris gayana,* Hunyani strain.
(3) *Brachiaria dictyoneura.*
(4) *Setaria phragmitoides* underplanted with the other three kinds.

The land was dressed with 200 lb. of potassic superphosphate per acre before it was ploughed and prepared to receive the root divisions of the grasses. Further dressings of 150 lb. per acre of sulphate of ammonia were applied each year. The grasses were planted at intervals of 36 by 18 inches. The stolons spread in all directions and almost completely covered the surface before growth was checked by the cold and dry winter season. Sufficient growth was made to allow the pastures to be lightly grazed during the first winter. Early in the following season, the stolons

covered the whole of the surface and a dense stand of leafy pasture was formed by midsummer. During the first two seasons, a single ox placed in each paddock was used to measure the productivity of the pasture, the number of days in which the ox found sufficient food to maintain its condition being recorded as " ox-grazing days." In subsequent years, instead of a single ox, from six to ten oxen were put into the paddock together and allowed to graze as long as it was deemed advisable. They were then withdrawn until the grass had recovered and made sufficient growth to allow it to be grazed again. Surprisingly little difference was found between the carrying capacities of the various grasses.

Over the 7-year period 1931 to 1937, the average number of " ox-grazing days" per acre per annum were as follows :—

	Days
Setaria phragmitoides underplanted with stoloniferous grasses	282
Digitaria pentzii	239
Brachiaria dictyoneura	231
Chloris gayana	230

The most productive years in the life of these pastures were the second, third and fourth. After the fifth year there was a marked falling off in the amount of growth produced, and weeds, particularly *Sporobolus* and *Eragrostis,* began to increase. In the sixth and seventh years the number of grazing days were reduced to little more than half of those of the best years. At this stage, it was decided to test the effect of topdressing the pastures with phosphatic fertilizer. The dressings used were :—

(1) 200 lb. per acre superphosphate.
(2) 200 lb. per acre raw rock phosphate.
(3) 400 lb. per acre raw rock phosphate.
(4) No phosphate.

These topdressings were applied in the form of a 4 × 4 Latin square, to each of the four grass paddocks.

Owing to their small size, it was not practicable to graze the individual plots, and the grass was allowed to grow until midsummer. No difference in the growth on the various plots could be discerned, and they were grazed off during late summer and autumn. In the second and third seasons after the applications of phosphates, dressings of 100 lb. per acre of sulphate of ammonia were applied on alternate blocks of the phosphated plots. Grazing of these was deferred until late in the season to allow quadrats to be cut and weighed on each of the fertilized plots. The results showed no increase in growth due to the dressings of phosphate, but the plots which received the nitrogenous dressing yielded approximately one half ton of hay per acre more than those to which phosphate only was applied.

Meanwhile *Sporobolus pyramidalis* and *Eragrostis patentipilosa* and other weeds increased considerably in the *Chloris* paddock. The *Digitaria* and *Setaria* paddocks also became somewhat weedy, but to a lesser extent than the *Chloris* paddock. A large proportion of the plants of *Setaria phragmitoides* weakened after the seventh year, and were eventually displaced by the stoloniferous components of the pasture and weeds. As regards weediness, the *Brachiaria dictyoneura* paddock contrasted very favourably with the others, in that it was almost weed-free. A few puny tufts

of *Sporobolus* could be found at wide intervals, but *Brachiaria* forms such a dense mat of both leaves and roots so near to the surface of the soil that few other plants are able to establish themselves in the same field. Unless this grass is grown on very fertile land, the bulk of the leafy portion is formed so near to the soil that cattle find it somewhat difficult to graze the whole of the growth, and unless sheep or horses are available to follow the cattle, the whole may not be fully utilized.

Of the four grasses in these trials, the *Digitaria* appears to be the most suitable one to plant when the object is the provision of pasturage for cattle. The growth of the *Brachiaria* is too short to provide good pasturage except when the soil is either naturally very fertile, or can be enriched with generous applications of nitrogenous substances. The *Chloris* was found to be more susceptible to changes in the rainfall than the other grasses. It grew quickly when climatic conditions were favourable, but within a few days of the cessation of precipitations the rate of growth was much reduced. The upright habit of the *Chloris* makes it more suitable for cutting for hay than the other grasses, but that is the only characteristic it possesses which is not found in the other grasses now under consideration.

Setaria phragmitoides is a tufted grass which produces large quantities of fodder, and continues to make new growth over a longer period than the others, but the growth is inclined to be stemmy and unpalatable except when young. The density of the tufts prevents the use of the mowing machine to remove surplus material. Thus, unless the growth is grazed off while it is young, it may become too coarse and unpalatable, in which condition it is impossible to utilize it.

Digitaria pentzii grows steadily in spite of droughty periods ; the whole of the growth is leafy, palatable and nutritious, even when it is quite dry, provided the current season's growth is not mixed with that of the previous year.

In order to compare *Digitaria pentzii* with the *Digitaria* species of more recent introduction, two 6 × 6 Latin squares were laid down in the season 1938–39. The following grasses were planted :—

> *Digitaria pentzii* var. ; *Digitaria pentzii,* Vryburg strain ; *Digitaria pentzii,* Messina strain ; *Digitaria* Port Elizabeth strain ; *Digitaria decumbens* ; *Digitaria valida,* Slurry strain ; *Digitaria* Malmaniesoog ; *Digitaria* Northern Rhodesia ; *Digitaria* Waterval ; *Panicum* Makarikari.

The growth has been cut once or twice each season as circumstances dictated and weights were recorded. *Panicum* Makarikari has yielded nearly twice as much material as *Digitaria pentzii,* but a considerable proportion of it consists of seed culms which would not be eaten by grazing animals. *Digitaria* Waterval has yielded 50 per cent more than the best strain of *Digitaria pentzii.* The whole of this material is leafy and would be eaten by cattle. *Digitaria* Malmaniesoog produced only 5 per cent more than *Digitaria pentzii.* Although the growth of *Digitaria decumbens* exceeded that of *Digitaria pentzii* during the first two seasons, it has been somewhat less productive since then. The other strains have yielded less fodder than *Digitaria pentzii,* Vryburg strain. It is seen, therefore, that *Panicum* Makarikari and *Digitaria* Waterval are the only grasses which promised to be more useful than *Digitaria pentzii* though *Digitaria* Malmaniesoog and *Digitaria decumbens* are worthy of further trial.

The majority of our farmers consider that the establishment of pastures by planting out root divisions is not practicable on a large scale, owing to the scarcity of

labour. For this reason, grasses which produce viable seed in sufficient quantities to permit them to be economically propagated by that means are particularly desired. Seeding strains of *Chloris gayana* have received the most attention from farmers so far. The local " Hunyani " strain does not produce much seed. A strain introduced from Northern Rhodesia produces seed very freely, but nearly the whole of its growth consists of wiry seed stems which have very little leafy material; chemical analysis indicates that its nutritive value is lower than that of other strains. Recently another strain was received from Tanganyika Territory. Its vigorous growth has earned for it the name of " Giant " Rhodes grass. The results obtained with this variety, so far, are very promising. It was sown for the first time this season in plots alternating with those of the common Australian variety, and its production is more than 100 per cent greater than the old type. Chemical analysis of material cut in the early flowering stage indicates that its nutritive qualities are at least as good as those of the imported kind. Although it produces seed fairly freely, its growth contains a large proportion of leafy material. Our experience of this grass is limited to a single season, and for that reason it is not possible to recommend its cultivation without reserve; unless it is shown to be a short-lived strain, there is every reason to think that it may prove to be a very valuable addition to our pasture grasses.

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ADDRESSES OF CONTRIBUTORS

H. C. Arnold, Pasture Research Committee, Salisbury, Southern Rhodesia.
A. R. Beddows, Welsh Plant Breeding Station, Penglais, Aberystwyth, Wales.
E. D. Bumpus, Agricultural Department, Ibadan, Nigeria.
A. D. Husband, Pasture Research Committee, Salisbury, Southern Rhodesia.
C. W. Lynn, Department of Agriculture, Accra, Gold Coast.
D. D. Paterson, Imperial College of Tropical Agriculture, Trinidad, British West Indies.
A. E. Romyn, Pasture Research Committee, Salisbury, Southern Rhodesia.
S. D. Ross, Agricultural Department, Ibadan, Nigeria.
J. L. Stewart, Director of Veterinary Services, Pong-Tamale, Northern Territories, Gold Coast.
S. D. Timson, Pasture Research Committee, Salisbury, Southern Rhodesia.
C. R. Turbet, Department of Agriculture, Suva, Fiji.
H. B. Waters, Director of Agriculture, Accra, Gold Coast.
R. O. Whyte, Imperial Bureau of Pastures and Forage Crops, Penglais, Aberystwyth, Wales.

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